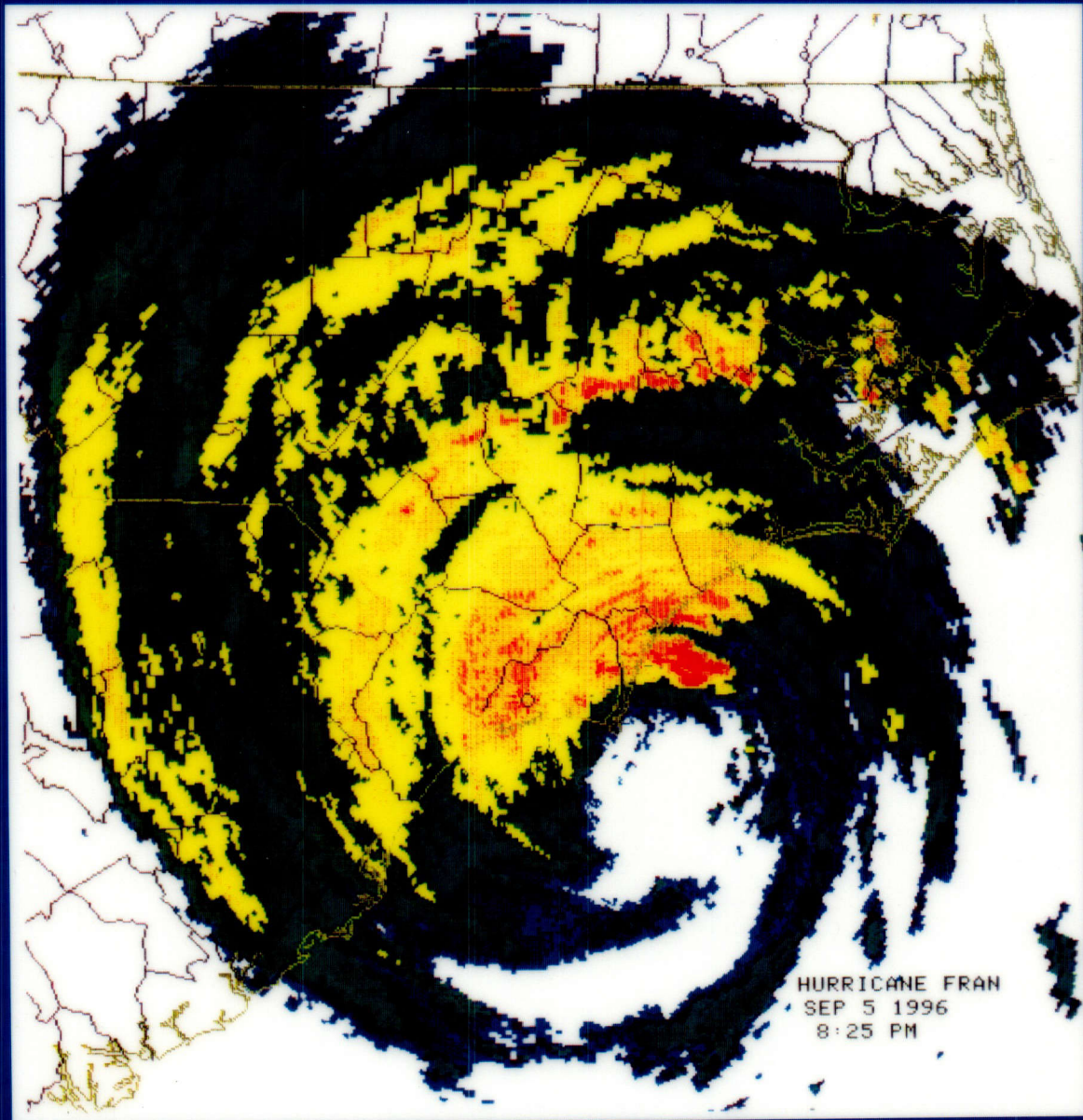


Transportation Analysis Update

North Carolina Hurricane Evacuation Restudy

Brunswick, New Hanover, Pender, and Onslow Counties



Prepared for
US Army Corps of Engineers, Wilmington District



Prepared by
Post, Buckley, Schuh & Jernigan, Inc.

**TRANSPORTATION ANALYSIS
NORTH CAROLINA HURRICANE EVACUATION RESTUDY
BRUNSWICK, NEW HANOVER, PENDER, AND ONSLOW COUNTIES**

Prepared for:

**Wilmington District
U.S. Army Corps of Engineers**

Prepared by:

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1.0 INTRODUCTION

1.1 OVERVIEW

With a number of recent hurricane strikes including Hurricanes Fran and Bertha in 1996, the southeastern coastal areas of North Carolina continue to fine tune their preparedness for more active hurricane seasons in the late nineties. The area faces a significant storm surge inundation potential and is extremely vulnerable to wave action on the barrier islands and freshwater flooding in low lying inland areas. Urban population centers in Wilmington and Jacksonville near the coast are susceptible to severe hurricane force winds well before a system decays after landfall.

For future hurricane threats, southeastern North Carolina faces evacuations of vulnerable population who have gained some limited evacuation experience and a road network that has been improved for evacuation movements (e.g., completion of I-40). The difficulties for evacuees will most likely be during peak tourist seasons where inland hotel/motel space is used up and where public shelter space is limited.

During a hurricane evacuation effort for southeastern North Carolina, a significant number of vehicles will have to be moved across the local and regional road network. The magnitude of evacuating vehicles will vary depending upon the intensity of the hurricane, publicity and warnings given about the storm, and certain behavioral response characteristics of the vulnerable population. During a typical evacuation, vehicles enter the road network at different times depending on the evacuee's response relative to an evacuation order or storm advisory. Conversely, vehicles leave the road network depending on both the planned destinations of evacuees and the availability of acceptable destinations such as public shelters, hotel/motel units and friend's or relative's homes in non-surge prone areas. Vehicles move across the road network from trip origin to destination at a speed dependent on the rate of traffic loadings on various roadway segments and the ability of the segments to handle a certain volume of vehicles each hour. Estimates of evacuation clearance time for the study area must include the effects of evacuation traffic generated by neighboring counties that will use other counties' roadways.

This report documents the study analysis inputs and findings. A separately bound appendix entitled Transportation Model Support Materials provides modeling information and data files too voluminous for this report.

1.2 ANALYSIS OBJECTIVES AND SCOPE

Recognizing the importance of updating hurricane evacuation clearance times for southeastern North Carolina, the US Army Corps of Engineers, Wilmington District hired Post, Buckley, Schuh and Jernigan, Inc. to perform the necessary tasks. The major objectives of the update were as follows:

- (1) Using new SLOSH/storm surge mapping developed for Brunswick, New Hanover, Pender and Onslow Counties, revise/establish a series of evacuation zones and scenarios for each county.
- (2) Quantify the population and dwelling units in each zone and quantify the potential evacuation population for each scenario.
- (3) Identify the existing evacuation roadway network noting improvements that have been made since the hurricane evacuation study was completed in the mid 1980's by the Corps of Engineers.
- (4) Determine the hurricane evacuation clearance times for each county and storm scenario.
- (5) Identify local and regional bottlenecks/critical roadway segments and where applicable, recommend general traffic control strategies.

Near the completion of the above tasks, monies became available to convert study graphics and data to a GIS format. Specifically, the following additional tasks were accomplished to enhance the presentation and use of transportation study products:

- (6) Translate CADD evacuation zone and road network graphics into ArcInfo/ArcView usable files.
- (7) Using the evacuation zone graphic for each county, develop graphics displaying:
 - permanent occupied dwelling units by evacuation zone
 - mobile home units by evacuation zone
 - seasonal dwelling units by evacuation zone
 - evacuating people by evacuation zone by scenario
 - public shelter demand by evacuation zone by scenario
- (8) Using the evacuation road network graphic for each county, develop graphics displaying:
 - number of lanes per roadway segment
 - evacuation traffic congestion by roadway segment by scenario
- (9) Deliver GIS digital files and graphics to each county.

1.3 COORDINATION AND REVIEW ACTIVITIES

A critical element in performing the study tasks was the coordination with the staff of each county, the State of North Carolina and the U.S. Army Corps of Engineers. Meetings were held during the spring and summer of 1996 to coordinate the various technical inputs to the analysis and to review graphics and evacuation statistics developed in the study. Mr. Al Bjorkquist and Mr. Mike Annand were the primary Corps of Engineers contacts.

2.0 TRANSPORTATION ANALYSIS AND INPUT ASSUMPTIONS

The hurricane evacuation transportation modeling performed for the study area required a number of important data inputs and assumptions regarding anticipated evacuation behavior. All hurricanes differ from one another in some respect. Therefore, it becomes necessary to set forth clear assumptions about storm characteristics and evacuee's expected response before this type of transportation modeling can begin. Not only does a storm vary in its track, intensity and size, but also in the way it is perceived by residents in potentially vulnerable areas. These factors can cause a wide variance in the behavior of the vulnerable population. Even the time of day at which a storm makes landfall influences the parameters of an evacuation response.

The hurricane evacuation transportation analysis results in clearance times based on a set of assumed conditions and behavioral responses. It is likely that an actual storm will differ from a simulated storm for which clearance times are calculated in this report. Therefore, a sensitivity analysis was performed during the transportation modeling. Those variables having the greatest influence on clearance time were identified and then varied to establish the logical range within which the actual input assumption values might fall.

Key input assumptions guiding the transportation analysis are grouped into four areas:

1. Storm Surge Areas and Evacuation Zones
2. Housing and Population Data
3. Behavioral Characteristics of the Evacuating Population
4. Roadway Network Assumptions

2.1 STORM SURGE AREAS AND EVACUATION ZONES

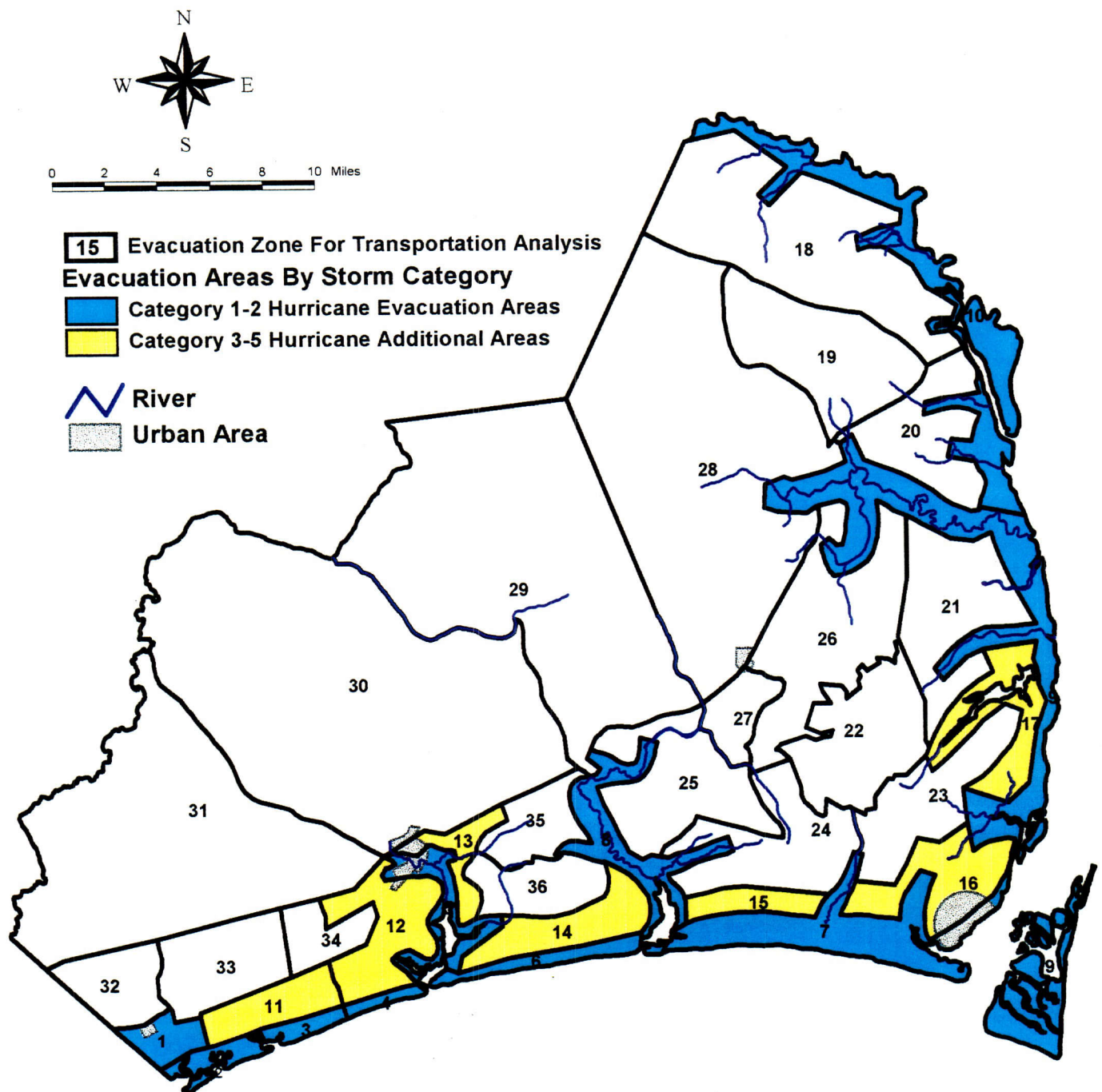
The first building block of the study was the development of evacuation zones for the transportation

modeling. Hurricane evacuation studies focus on dwelling units within the potential storm surge flooded areas of a county and inland mobile homes which would be vulnerable to hurricane force winds. Therefore, an entire county is divided into zones with flood areas corresponding to the SLOSH mapping developed in that county. For this study area, SLOSH inundation mapping was prepared by the North Carolina Center for Geographic Information and Analysis under contract to the U.S. Army Corps of Engineers, Wilmington District. The center used updated SLOSH inundation values developed by the National Hurricane Center.

Figures 2-1 through 2-4 illustrate the evacuation zones developed for the analysis for Brunswick, New Hanover, Pender and Onslow Counties, respectively. The zone boundaries were set up to relate to well known manmade or natural features, census boundaries, and roadways. **Historically, North Carolina counties have not evacuated by the zone system developed in the transportation analysis. This is not a concern as long as the counties attempt to evacuate those general areas shown in blue and yellow for the appropriate storm category, as well as mobile homes in the inland areas.** Table 2-1 summarizes the assumed vulnerability of each evacuation zone by storm scenario and county.

Figure 2-1

Evacuation Zones For Transportation Analysis

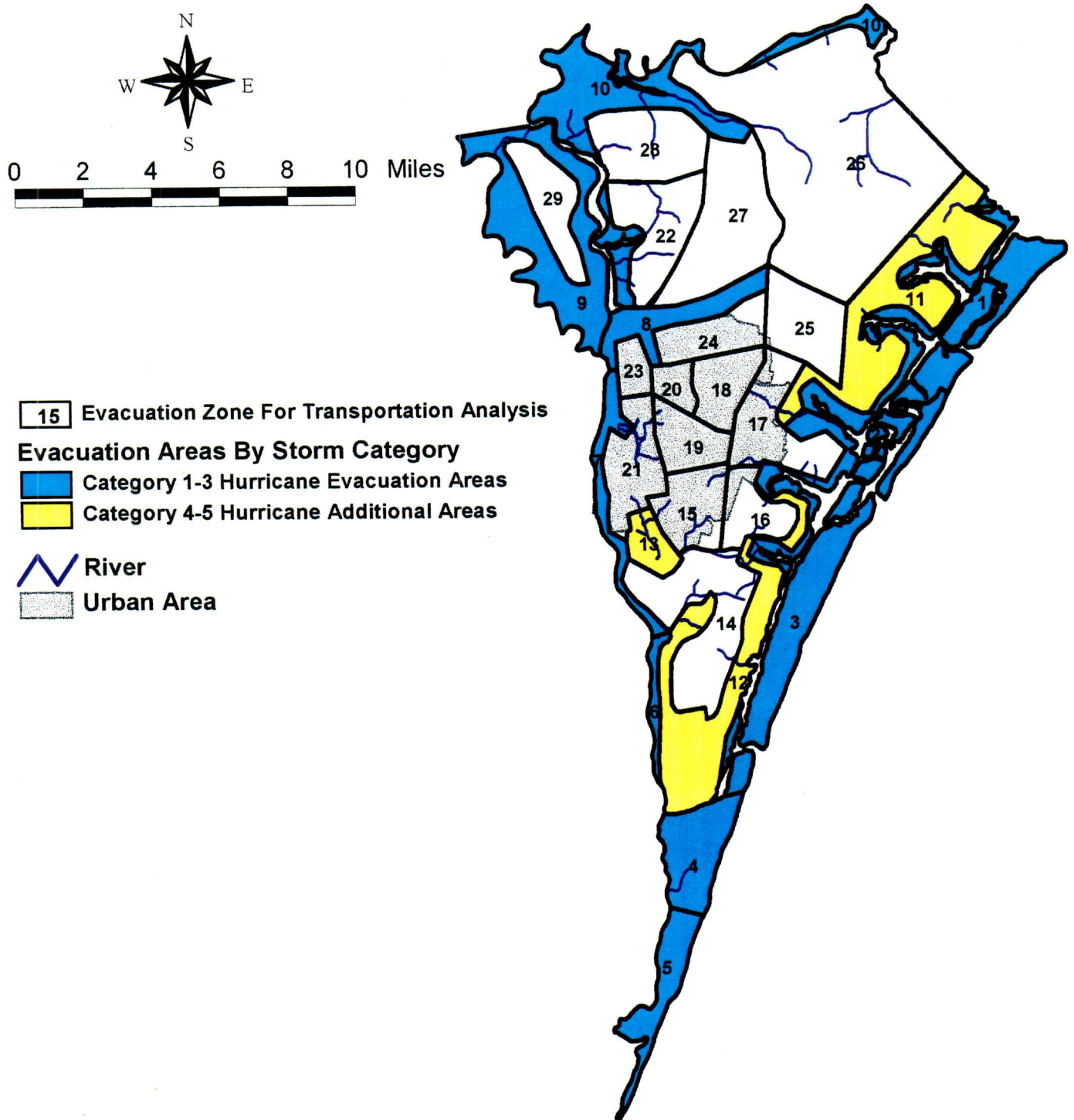


Brunswick County

North Carolina Hurricane Evacuation Restudy

Figure 2-2

Evacuation Zones For Transportation Analysis

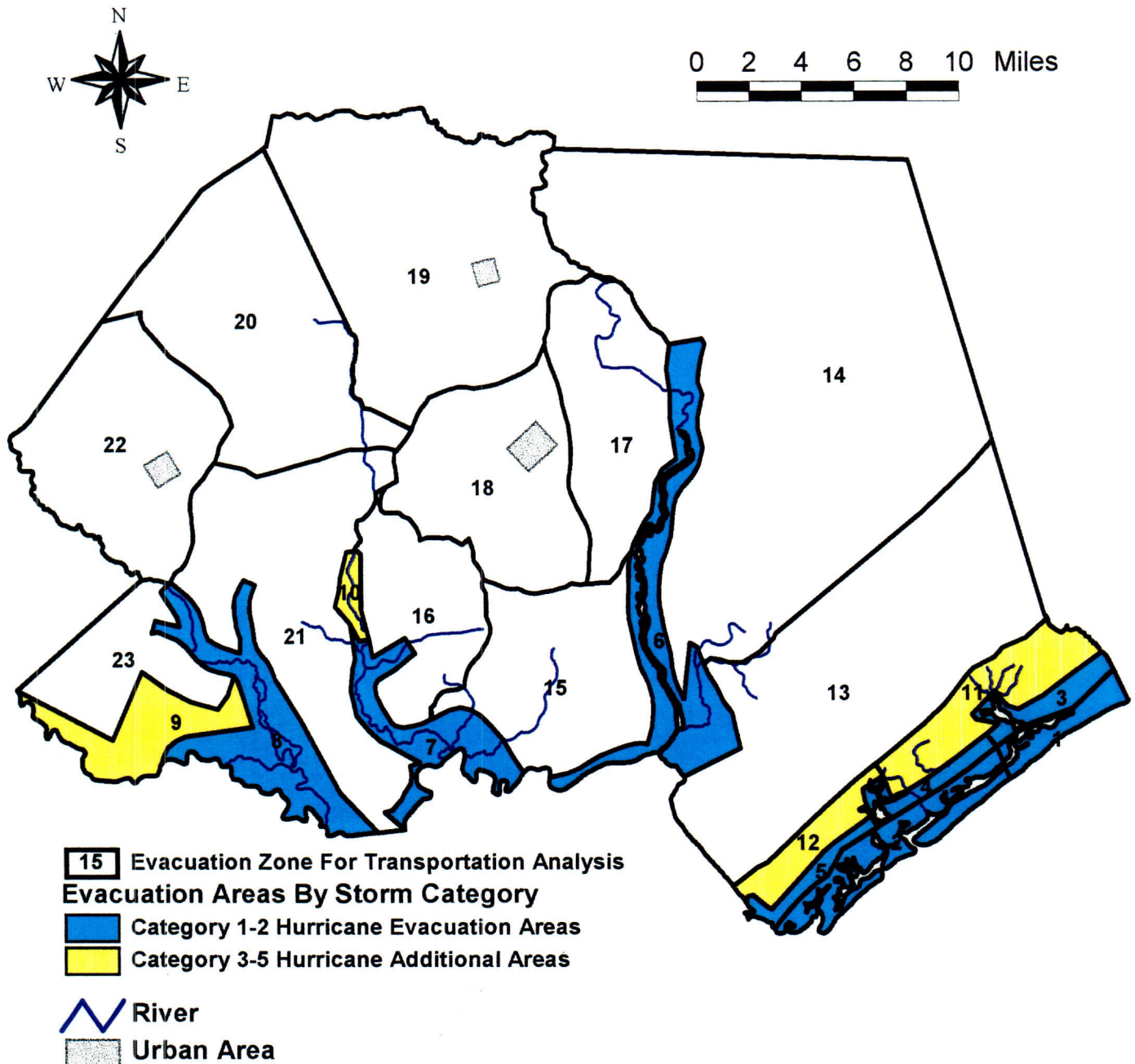


New Hanover County

North Carolina Hurricane Evacuation Restudy

Figure 2-3

Evacuation Zones For Transportation Analysis

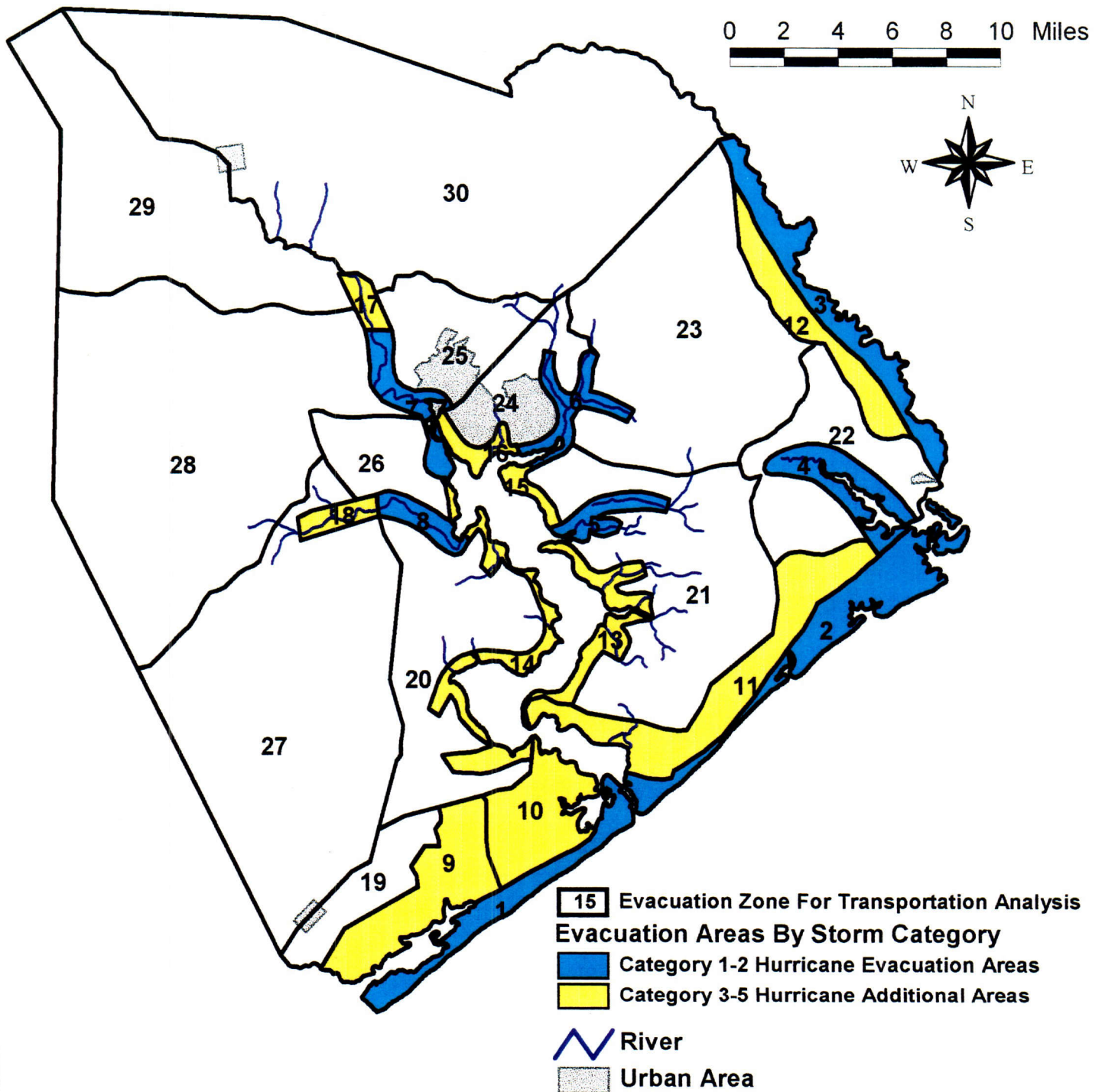


Pender County

North Carolina Hurricane Evacuation Restudy

Figure 2-4

Evacuation Zones For Transportation Analysis



Onslow County

North Carolina Hurricane Evacuation Restudy

Table 2-1

**CLEARANCE TIME ANALYSIS EVACUATION ZONES
ASSUMED VULNERABILITY BY STORM SCENARIO BY COUNTY**

North Carolina Hurricane Evacuation Restudy

Number of Zones	Storm Scenarios	All Residents in Zones:	Mobile Home Residents Only in Zones:
36	Brunswick County Category 1-2 Hurricane	1 - 10	11 - 36
	Category 3-5 Hurricane	1 - 17	18 - 36
29	New Hanover County Category 1-2 Hurricane	1 - 10	11 - 29
	Category 3-5 Hurricane	1 - 13	14 - 29
23	Pender County Category 1-2 Hurricane	1 - 8	9 - 23
	Category 3-5 Hurricane	1 - 12	13 - 23
30	Onslow County Category 1-2 Hurricane	1 - 8	9 - 30
	Category 3-5 Hurricane	1 - 18	19 - 30

2.2 HOUSING AND POPULATION DATA

To quantify the number of housing units and population living within evacuation zones, 1990 Census data was provided to PBS&J from the North Carolina Center for Geographic Information and Analysis. This data was supplemented by current year mobile home and permanent occupied dwelling unit data provided by each county. Table 2-2 summarizes this data for each county. The Transportation Model Support Document provides the data by evacuation zone.

The use of GIS technology (ArcInfo, Arcview) facilitated the production of color graphics which could be used to quality control and display study inputs. Figures 2-5 through 2-8 illustrate the 1996 permanent dwelling units by evacuation zone by county. Mobile home units by evacuation zone by county are shown in Figure 2-9 through 2-12. Figures 2-13 through 2-16 show seasonal units by evacuation zone by county.

Table 2-2

**1996 POPULATION DWELLING UNIT SUMMARY
BY COUNTY**

North Carolina Hurricane Evacuation Restudy

Brunswick County

Permanent Population - 60,000 people

Permanent occupied dwelling units - 23,660 units

Mobile homes - 9,000 units (7,000 of which are permanent singlewides)

Tourist/seasonal units - 14,900 units (7,000 of which are mobile homes)

New Hanover County

Permanent Population - 130,100 people

Permanent occupied dwelling units - 52,000 units

Mobile homes - 5,300 units

Tourist/seasonal units - 3,600 units

Pender County

Permanent Population - 30,300 people

Permanent occupied dwelling units - 11,680 units

Mobile homes - 5,300 units

Tourist/seasonal units - 2,500 units

Onslow County

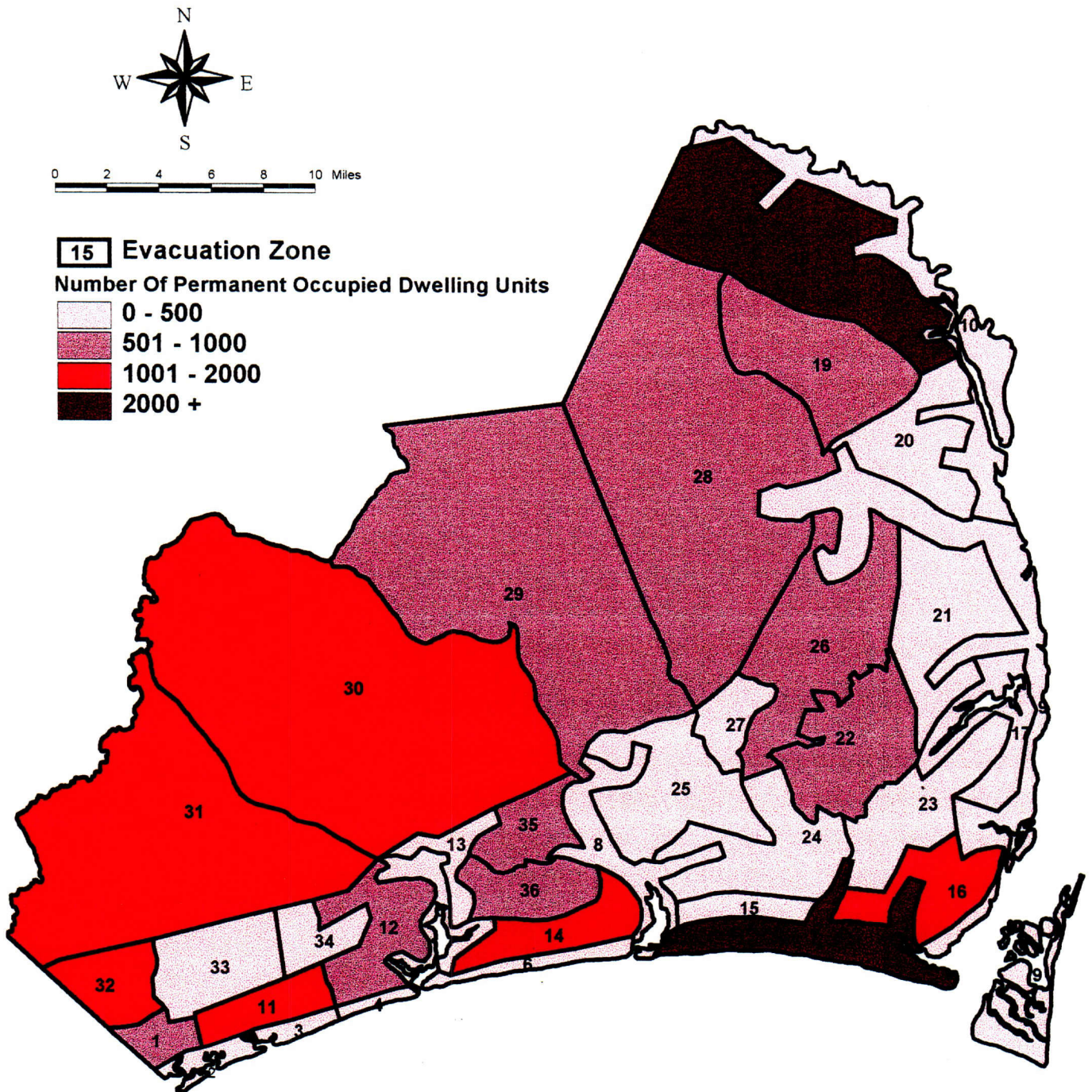
Permanent Population - 149,800 people

Permanent occupied dwelling units - 41,100 units

Mobile homes - 12,220 units

Tourist/seasonal units - 1,870 units

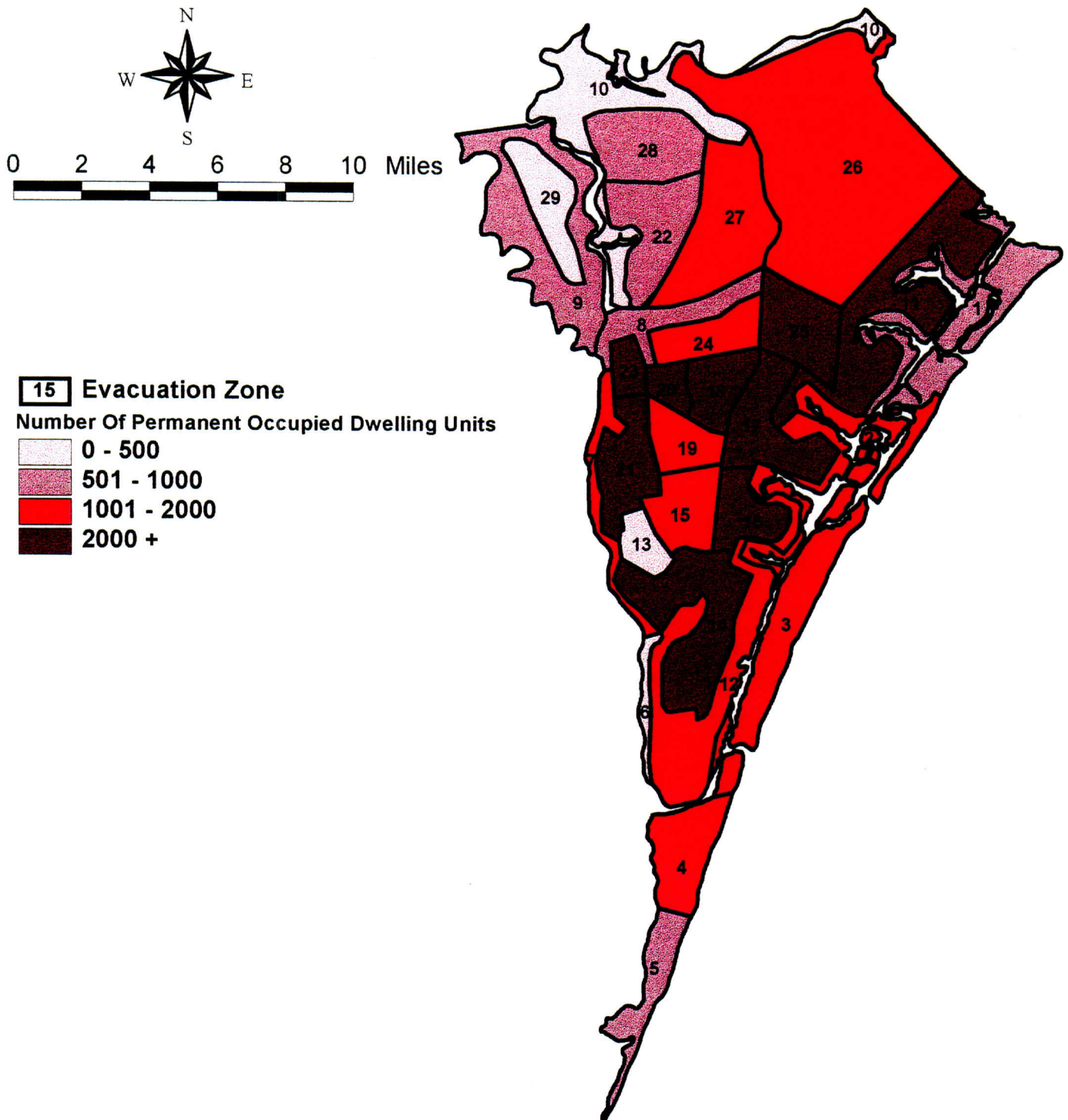
Figure 2-5 Permanent Occupied Dwelling Units



Brunswick County
North Carolina Hurricane Evacuation Restudy

Figure 2-6

Permanent Occupied Dwelling Units

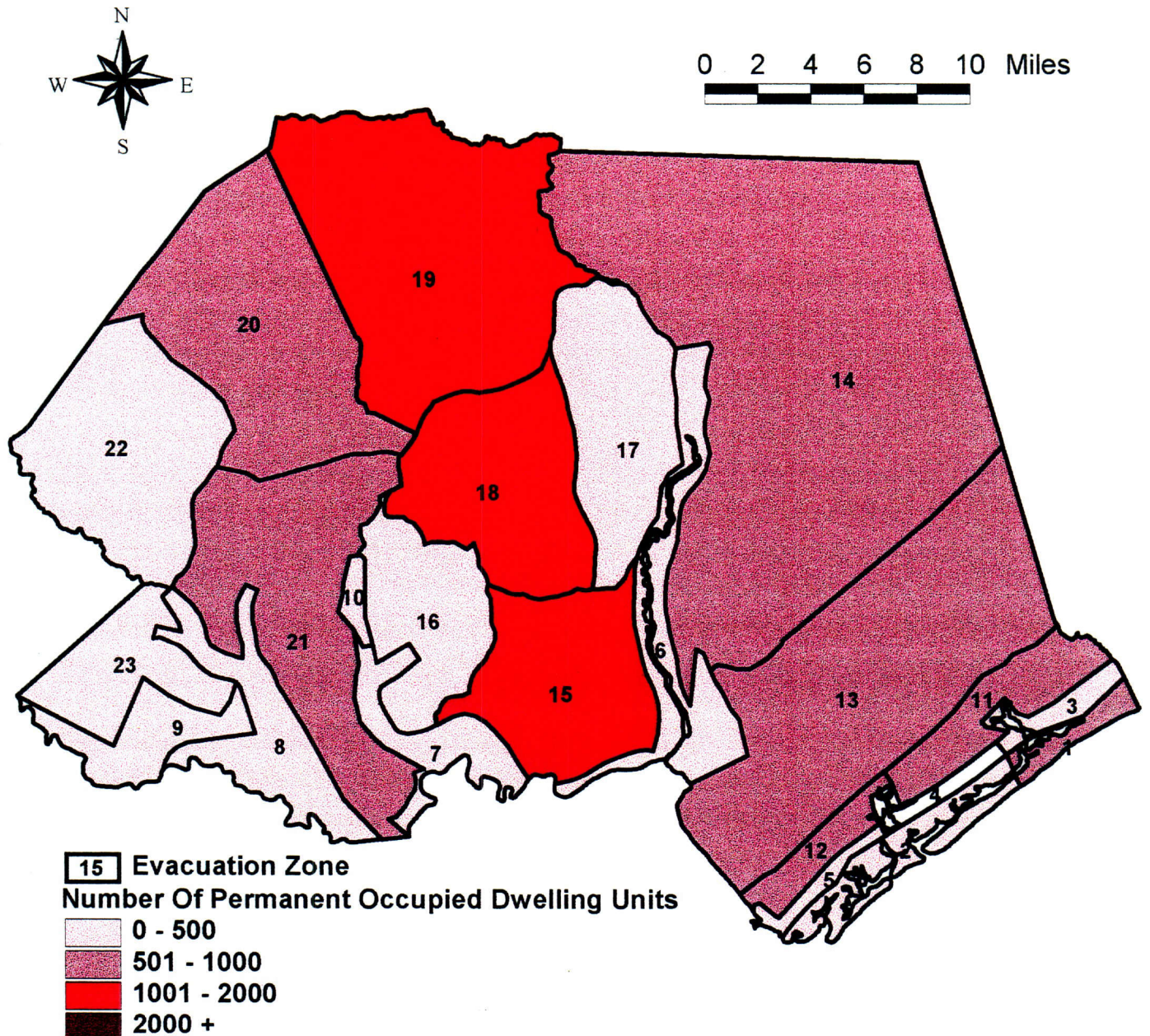


New Hanover County

North Carolina Hurricane Evacuation Restudy

Figure 2-7

Permanent Occupied Dwelling Units

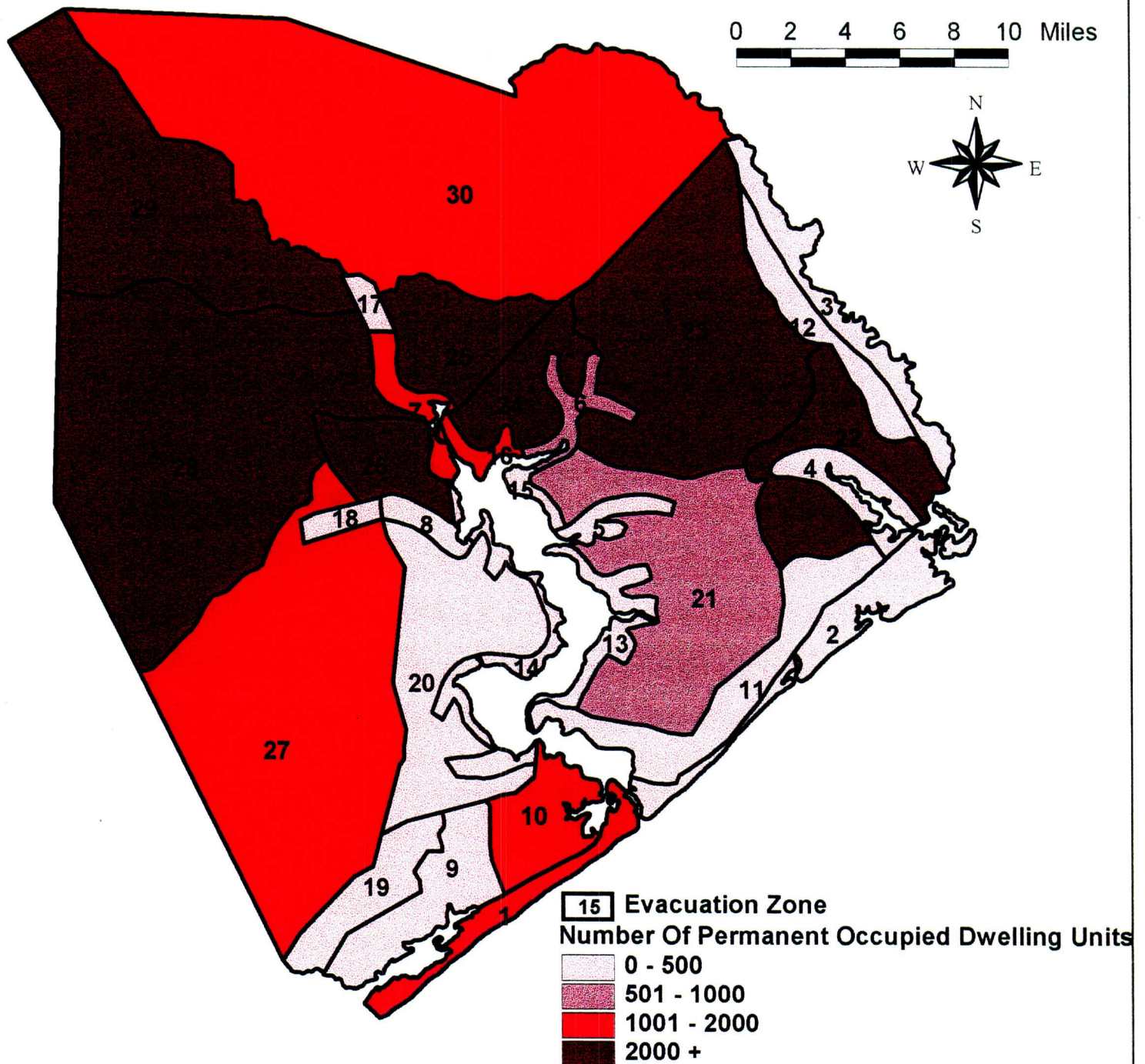


Pender County

North Carolina Hurricane Evacuation Restudy

Figure 2-8

Permanent Occupied Dwelling Units

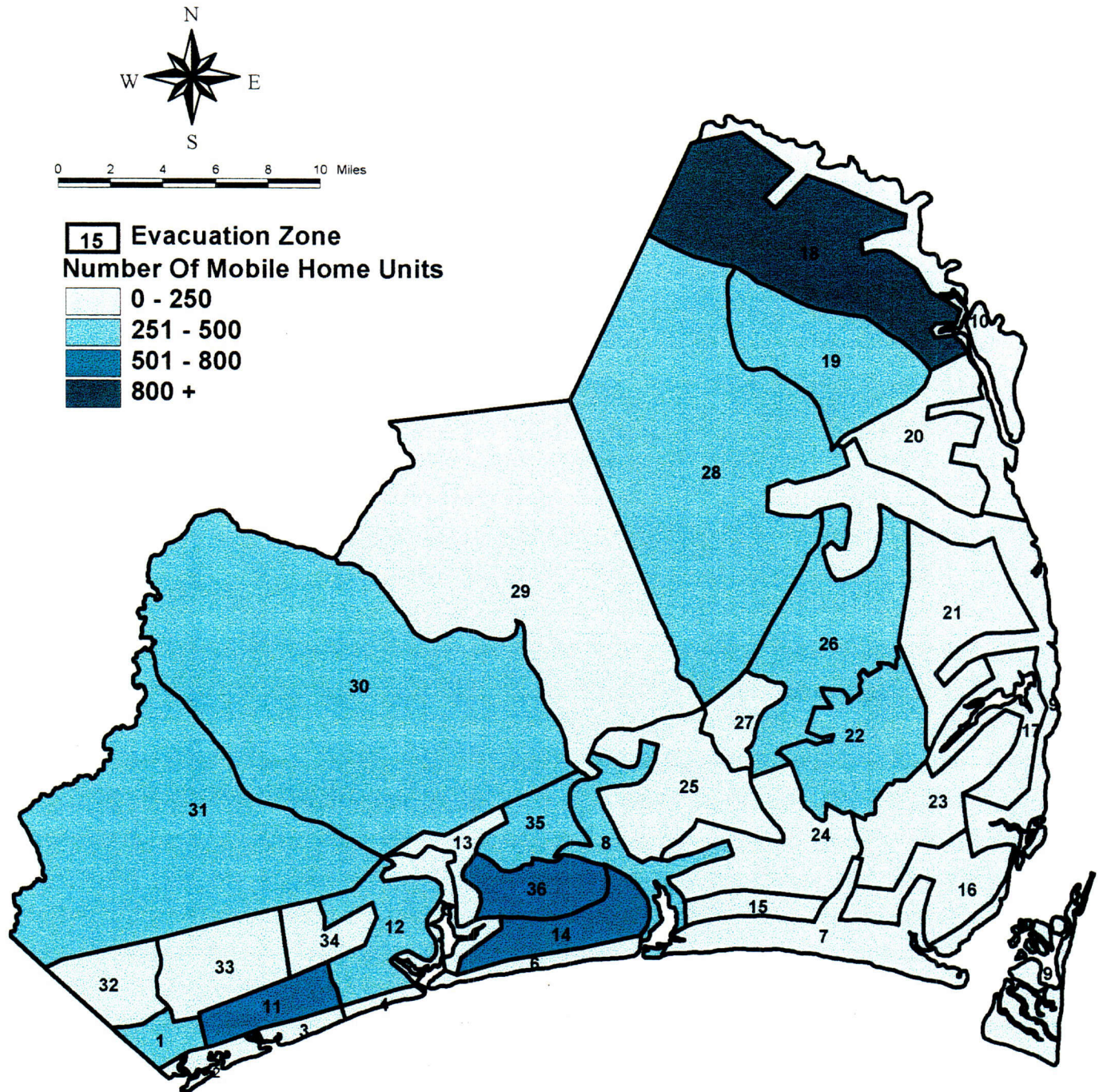


Onslow County

North Carolina Hurricane Evacuation Restudy

Figure 2-9

Mobile Home Units

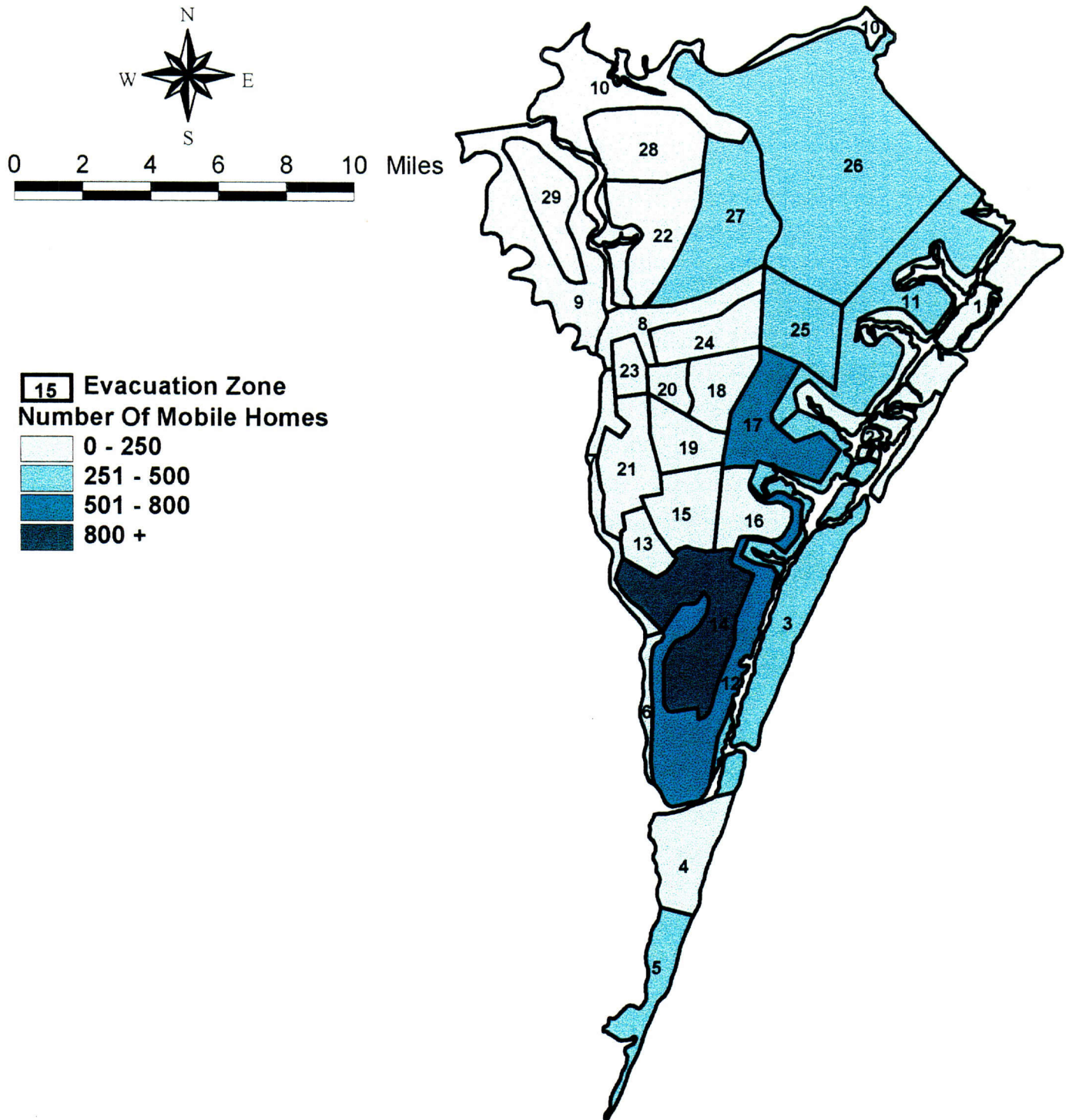


Brunswick County

North Carolina Hurricane Evacuation Restudy

Figure 2-10

Mobile Home Units

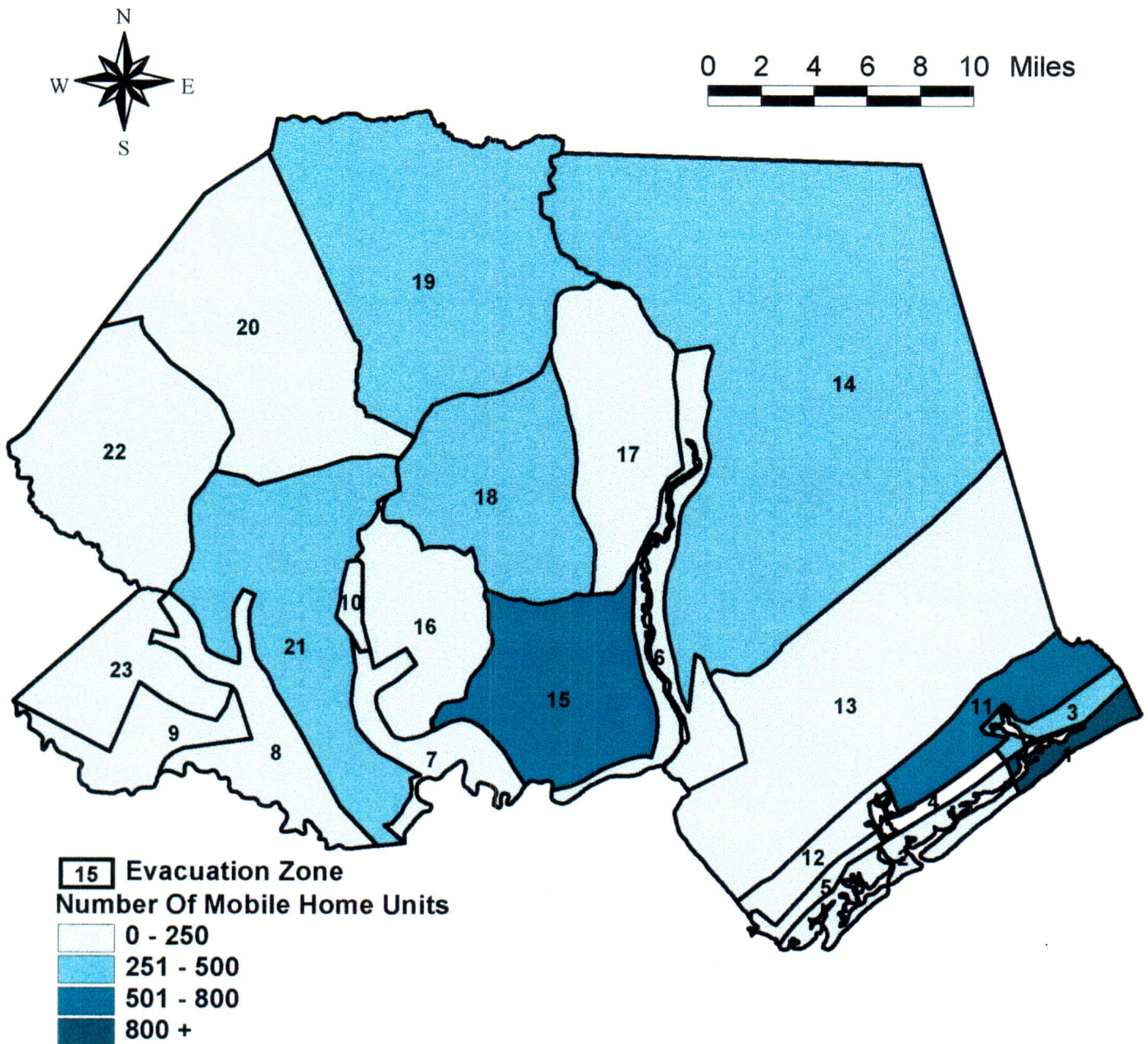


New Hanover County

North Carolina Hurricane Evacuation Restudy

Figure 2-11

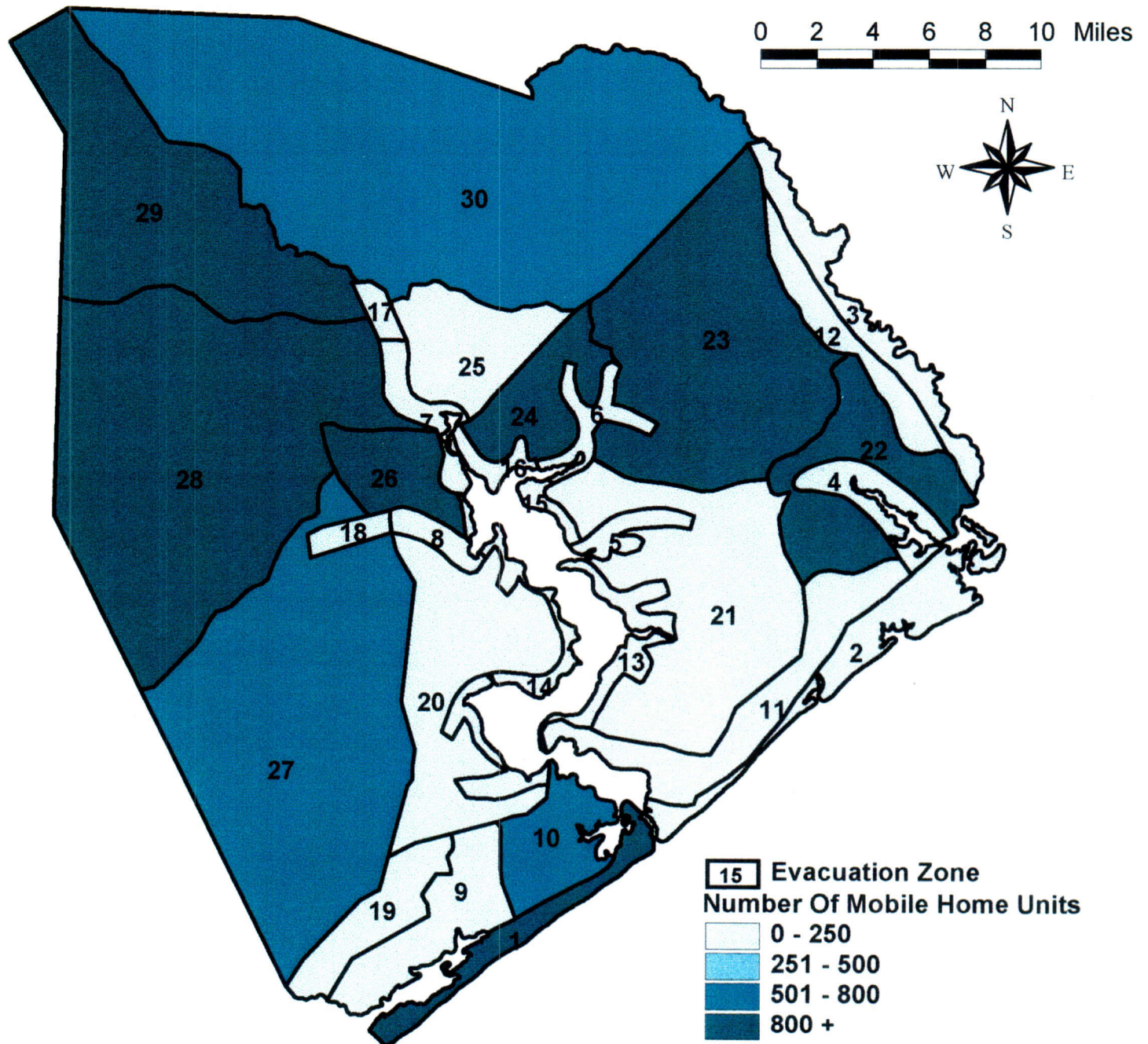
Mobile Home Units



Pender County

North Carolina Hurricane Evacuation Restudy

Figure 2-12
Mobile Home Units

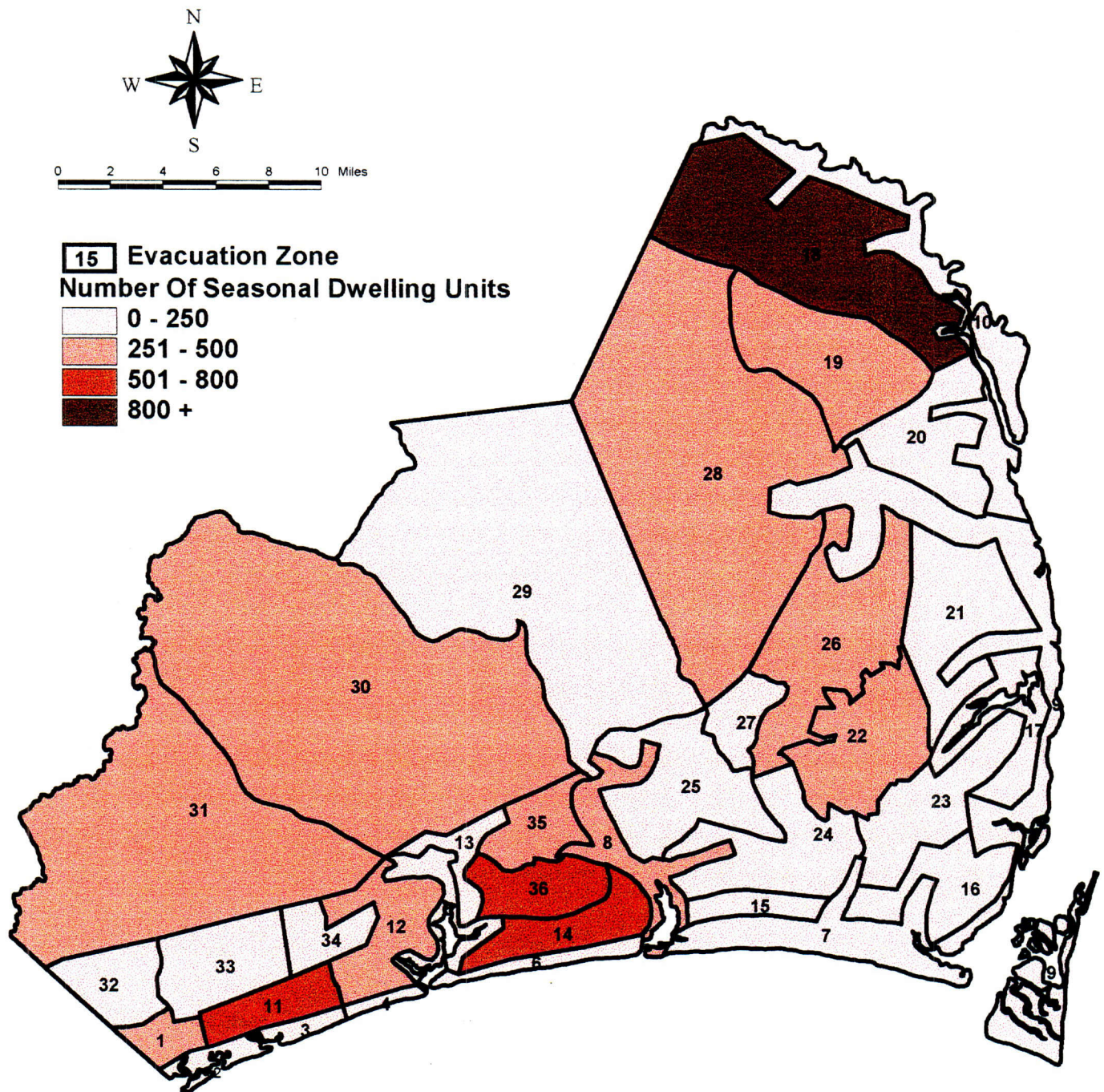


Onslow County

North Carolina Hurricane Evacuation Restudy

Figure 2-13

Seasonal Dwelling Units

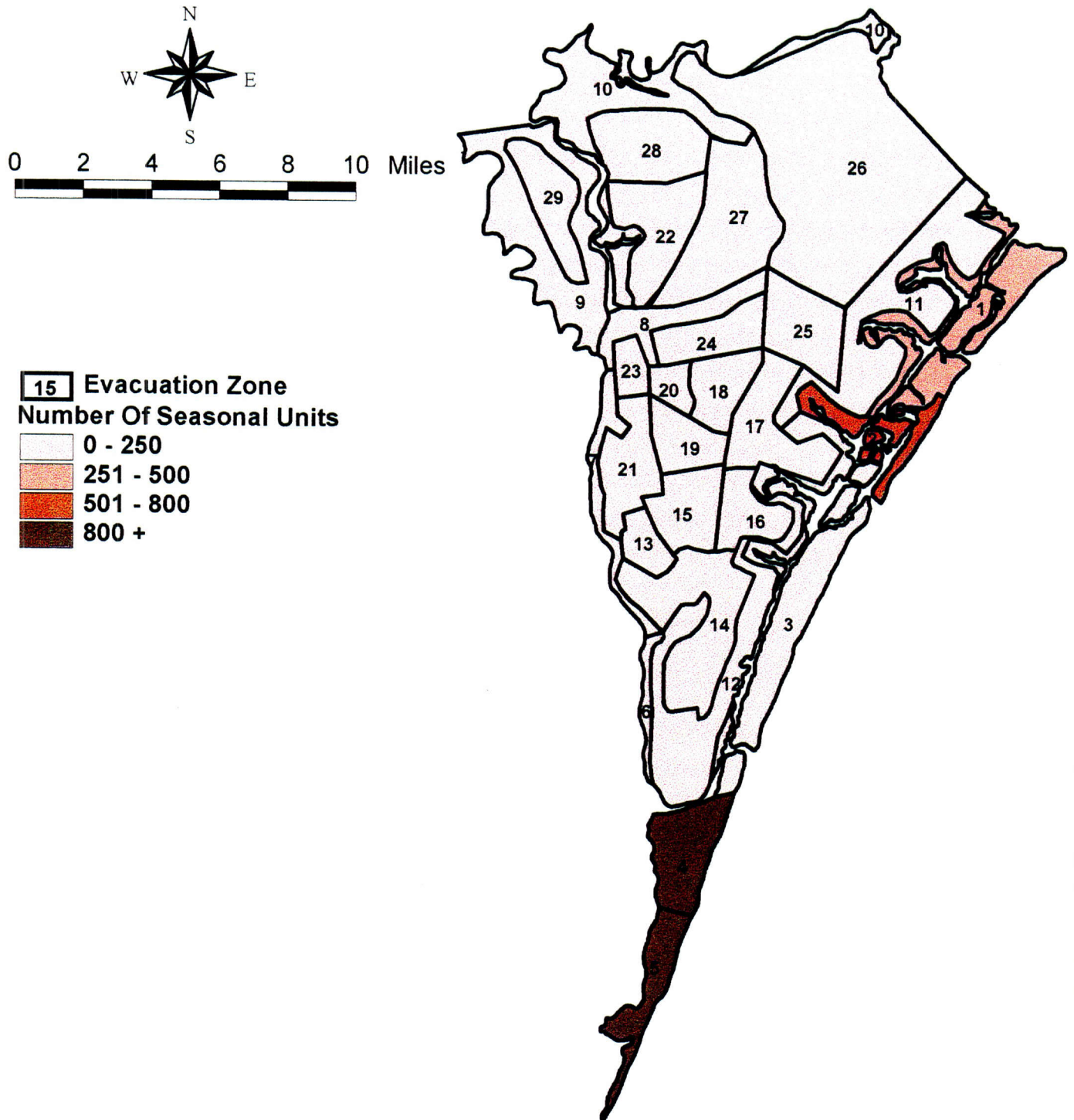


Brunswick County

North Carolina Hurricane Evacuation Restudy

Figure 2-14

Seasonal Dwelling Units

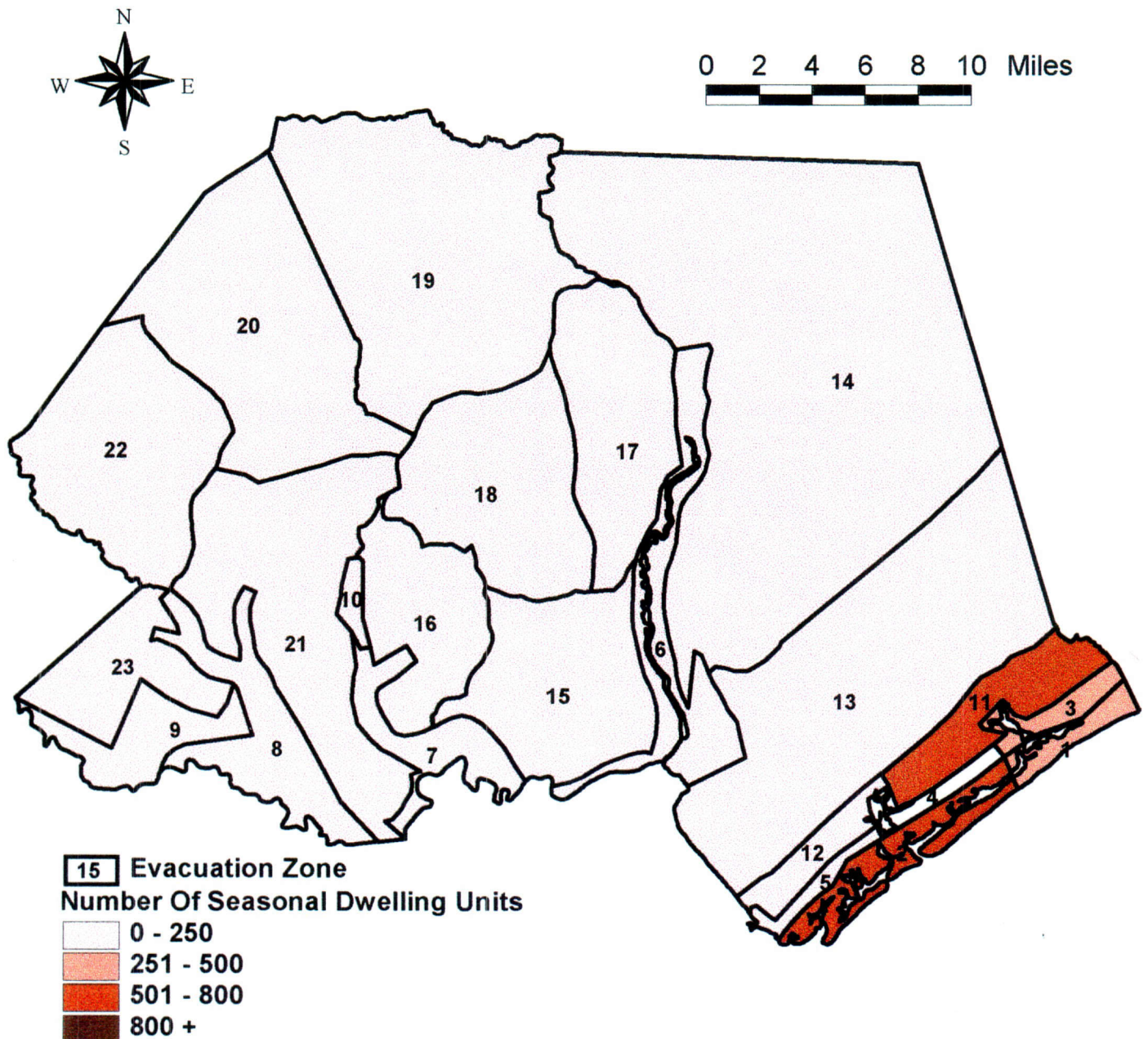


New Hanover County

North Carolina Hurricane Evacuation Restudy

Figure 2-15

Seasonal Dwelling Units

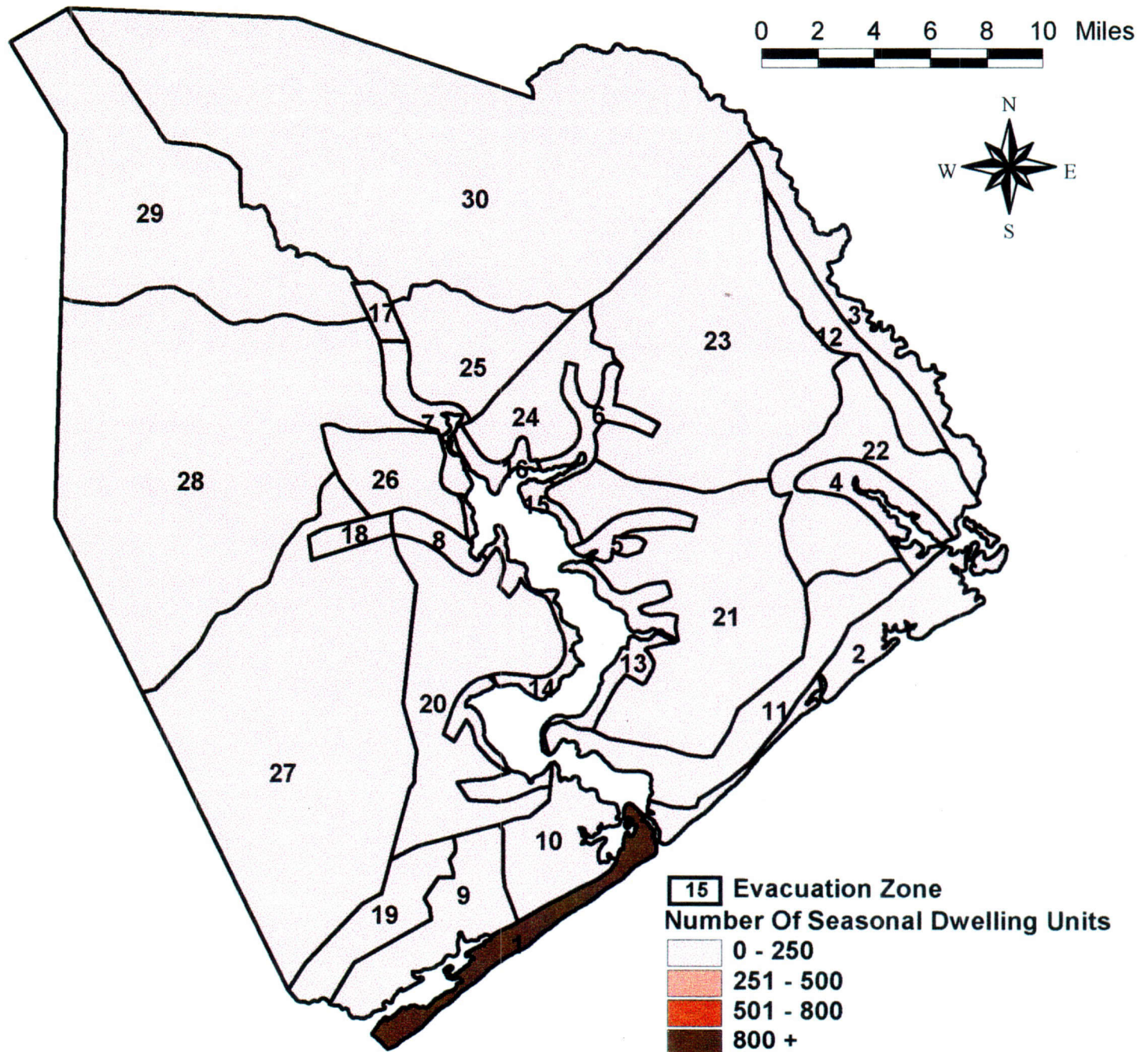


Pender County

North Carolina Hurricane Evacuation Restudy

Figure 2-16

Seasonal Dwelling Units



Onslow County

North Carolina Hurricane Evacuation Restudy

2.3 BEHAVIORAL ASSUMPTIONS

Recognizing that the future evacuation of an endangered population due to a hurricane approaching the southeastern North Carolina study area will involve the evacuation decisions of thousands of individuals and households, PBS&J reviewed available sources of evacuation behavioral surveys and analyses available for the North Carolina coast. As sources of data were reviewed, the PBS&J team concentrated on data related to the following behavioral aspects:

- Participation rates - what percent of the population in different areas will evacuate their dwelling units for future hurricane threats?
- Evacuation rapidity of response rates - how quickly will evacuees respond to what local officials are telling them to do?
- Destination percentages - what percent of the population by county sub-area will evacuate to local public shelters, local hotel/motels, local friends' and relatives' homes, or out of the county entirely?
- Vehicle usage - of the vehicles available to the households, what percent of those vehicles will be used in an evacuation?

PBS&J developed behavioral assumptions by evacuation zone relying on the following sources of input:

- Discussions concerning expected behavioral response with emergency management staff in each county
- Review of past behavioral studies as a part of various hurricane planning efforts conducted by the U.S. Army Corps of Engineers, Wilmington District.

- Behavioral research and recommendations by Hazards Management Group for the region; particularly behavioral data collected for the 1995 Felix response in North Carolina and recent residential behavioral surveys accomplished in the study area.

Even with these resources, a great deal of judgment was involved in developing the needed parameters on a zone by zone basis. However, PBS&J has had a wealth of experience both pre- and post-Emily/Felix in North Carolina and around the country in developing and applying behavioral parameters for evacuation analysis. PBS&J is also currently participating in post-Bertha/Fran evacuation assessments within the study area.

Key assumptions by zone were laid out by scenario for review before modeling commenced. Summary sheets of all key assumptions are provided in the trip generation portion of the Transportation Model Support Document. Participation rates assumed for all evacuation zones in a county and for each scenario are provided in the model document as well. Key factors behind the participation assumptions are as follows:

- Zones that will be evacuated for storm surge were assumed to have a 100% participation rate. Even though in actuality these rates will be lower, as a matter of public safety the clearance times calculated in this study should allow those who are vulnerable to storm surge the opportunity to evacuate whether they choose to or not.
- All mobile homes in inland zones are assumed to evacuate.
- As time passes from the Fran event, participation by theoretically non-vulnerable residents will diminish. A small portion of the theoretically non-vulnerable population was also assumed to evacuate in the modeling. This percentage will be higher than what was used for more intense hurricanes (2% - 10%), but will be balanced out with the less than 100% of surge residents who will participate in an actual event.

A critical behavioral aspect that must be considered for the transportation analysis is the rapidity of evacuation response of the evacuating population. Behavioral data from research of past hurricane evacuation shows that mobilization and actual departures of the evacuating population can occur over a period of many hours or over a very brief time. For the North Carolina restudy, clearance times were tested for three evacuation response rates represented by different behavioral response curves. Behavioral response curves describing mobilization by the vulnerable population, define the rate at which evacuating vehicles attempt to load onto the evacuation street network for each hourly interval relative to an evacuation order or advisory. These response curves shown in Figure 2-17 range from rapid response to long response and are intended to include a potential range of possible mobilization times that might be experienced in a future hurricane evacuation situation. For sensitivity analysis, the mobilization/traffic loading time was varied between four hours and ten hours.

The percentage of evacuees assumed to go to one of four general destination types was another important behavioral input to the transportation analysis. Evacuee destination percentages have been discussed with emergency management staff, and after careful review of information provided in the available behavioral studies, assumptions were developed by zone. Figures were developed for the expected percent of evacuees going to local public shelters, hotel/motel units, the home of a friend or relative, or out of the county entirely. Destination percentages were varied for each evacuation zone in the county depending on category of risk (distance from coastline) or special characteristics of a zone such as high number of mobile home units.

It should be noted that destination percentages refer to destination desires. Specific out of county destination assumptions are provided in Table 2-3. Where destination desires could not be satisfied by in-county capacities (e.g., hotel/motels), the transportation analysis assumed that these evacuees would have to leave the county to find acceptable refuge. One important behavioral aspect built into the rates is that of a larger percentage of evacuees going out of county for each successive step in storm intensity scenario. Also, in the lower intensity scenarios in the non-surge area, most of the evacuees are mobile home residents who have a higher propensity to use public shelters.

BEHAVIORAL RESPONSE CURVES

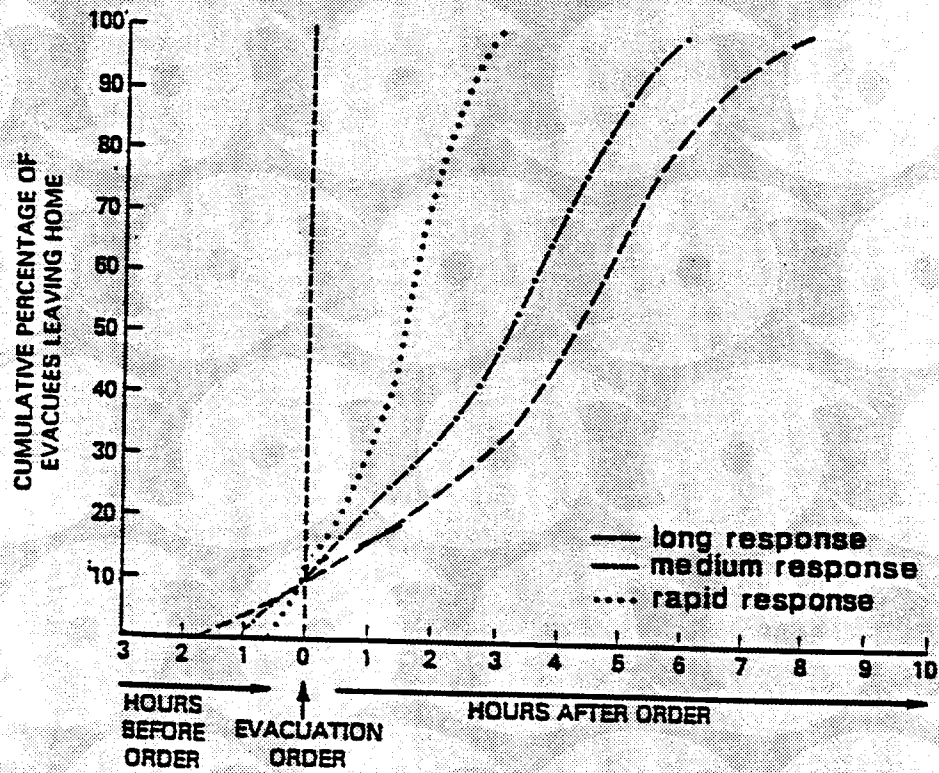


Figure 2-17

TABLE 2-3**ASSUMED OUT OF COUNTY EVACUEE DESTINATIONS
North Carolina Hurricane Evacuation Restudy**

Percent From:

Going To:	Brunswick	New Hanover	Pender	Onslow
Raleigh/ Piedmont areas	29%	47%	44%	44%
Lumberton- Fayetteville	33%	19%	10%	16%
Charlotte and western NC	15%	17%	10%	8%
Areas north and east of I-95	4%	9%	21%	24%
South Carolina/ Georgia	14%	4%	7%	8%
New Hanover County	5%	---	4%	---
Pender County	---	4%	---	---
Onslow County	---	---	4%	---
	100%	100%	100%	100%

A final behavioral assumption refers to vehicle usage during the evacuation. Vehicle usage percentages refer to the percentage of vehicles available at the home origin that are assumed to be used in the evacuation. Vehicle usage percentages were 65% to 75% (depending on distance from the coastline) for the study transportation analysis.

2.4 ROADWAY NETWORK CHARACTERISTICS

A final group of assumptions used for input to the transportation analysis is related to the roadway system chosen for the evacuation network and traffic control measures considered for traffic movement. Although the assumptions developed for the transportation analysis are general, the efforts at county and municipal levels regarding traffic control and roadway selection must be quite detailed. Detailed law enforcement assignments to major bottlenecks involves extensive coordination among local and state officials. This study does not presume to replace those efforts, but seeks to quantify the time elements within which such personnel would operate.

In choosing roadways to be used for the evacuation network, an effort was made to include street facilities with sufficient elevations, little or no adjacent tree coverage, substantial shoulder width and surface, and roadways already contained in existing hurricane evacuation plans. In an area such as southeastern North Carolina, where there are urban and rural low lying streets that flood in heavy rainfall events, these criteria are difficult to meet. Another objective was to include arterials that would provide the smoothest (least disjointed) possible traffic flow.

In order to determine the routing of evacuation, a representation of the roadway system was developed. A "link-node" system was developed to identify roadway sections. Nodes are used to identify the intersection of two roadways or changes in roadway characteristics. Links are the roadway segments as defined by the nodes when connected. Each link is identified by a letter designation. Figures 2-18 through 2-21 illustrates the coded evacuation network with link names and zone connections to the links shown by open circles and dashed lines.

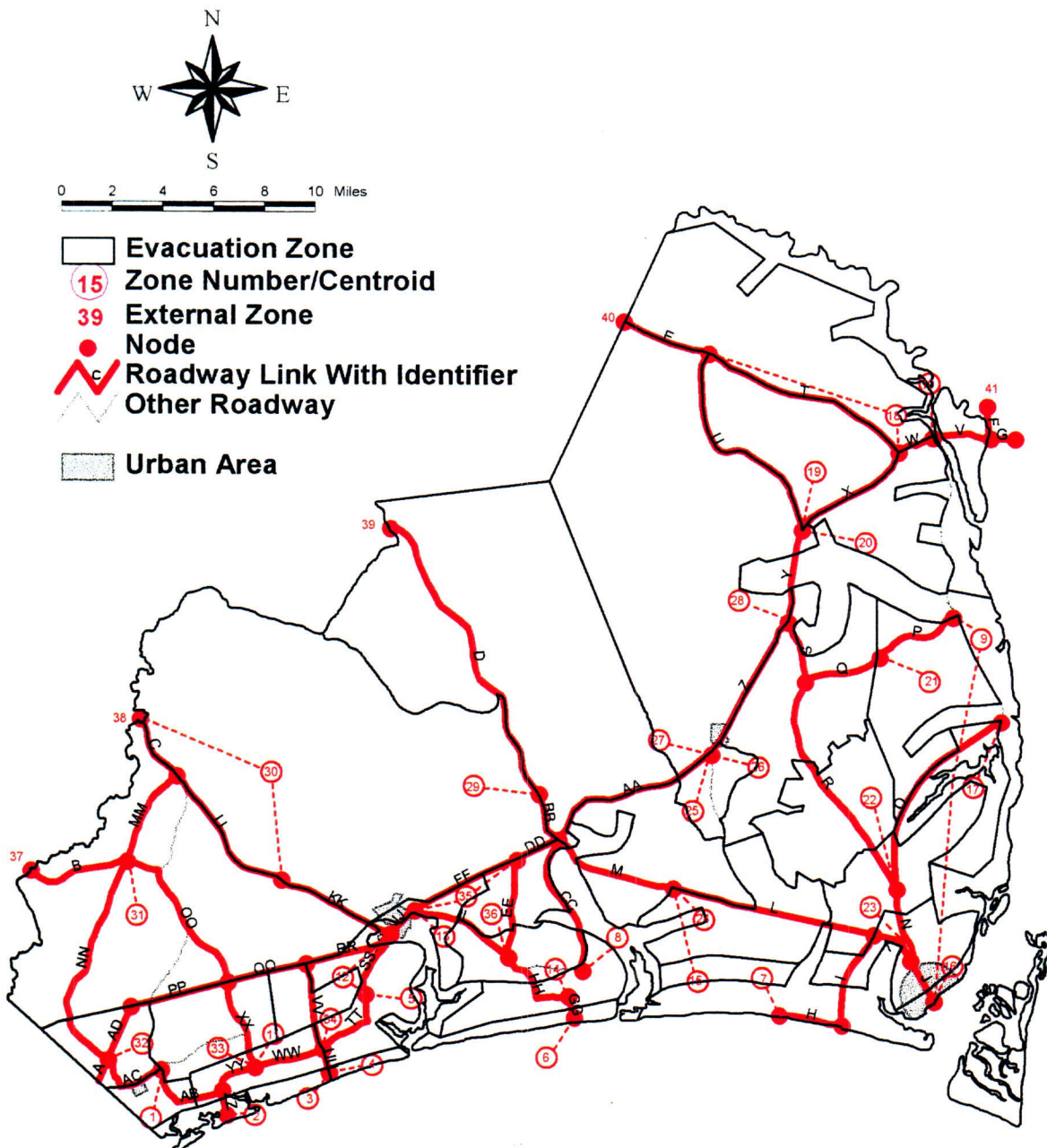
Once the links and nodes were established for the evacuation routes, directional traffic service volumes at Level of Service D were established for each link for 1996. This was accomplished by ascertaining number of lanes, facility type, and area type information from highway maps available locally and "field checks"/updating accomplished by PBS&J. Tables were then used to specify a directional, level of service D service volume based on link characteristics. Figures 2-22 through 2-25 show the 1996 directional service volumes and number of lanes for the evacuation clearance time analysis.

Important assumptions concerning the evacuation road network for the analysis which must be mentioned are:

- The evacuation of all vehicles will occur prior to the arrival of sustained tropical storm winds (39 mph) and storm inundation of evacuation routes
- Provisions will be made for the removal of vehicles in distress on the network through aggressive incident management and agreements worked out with tow truck operators
- Signal timings will be "actuated" to provide the most green time for westbound movements away from the coast
- The U.S. Coast Guard will be contacted to "lock down" draw bridges once evacuation orders or advisories are issued

Figure 2-18

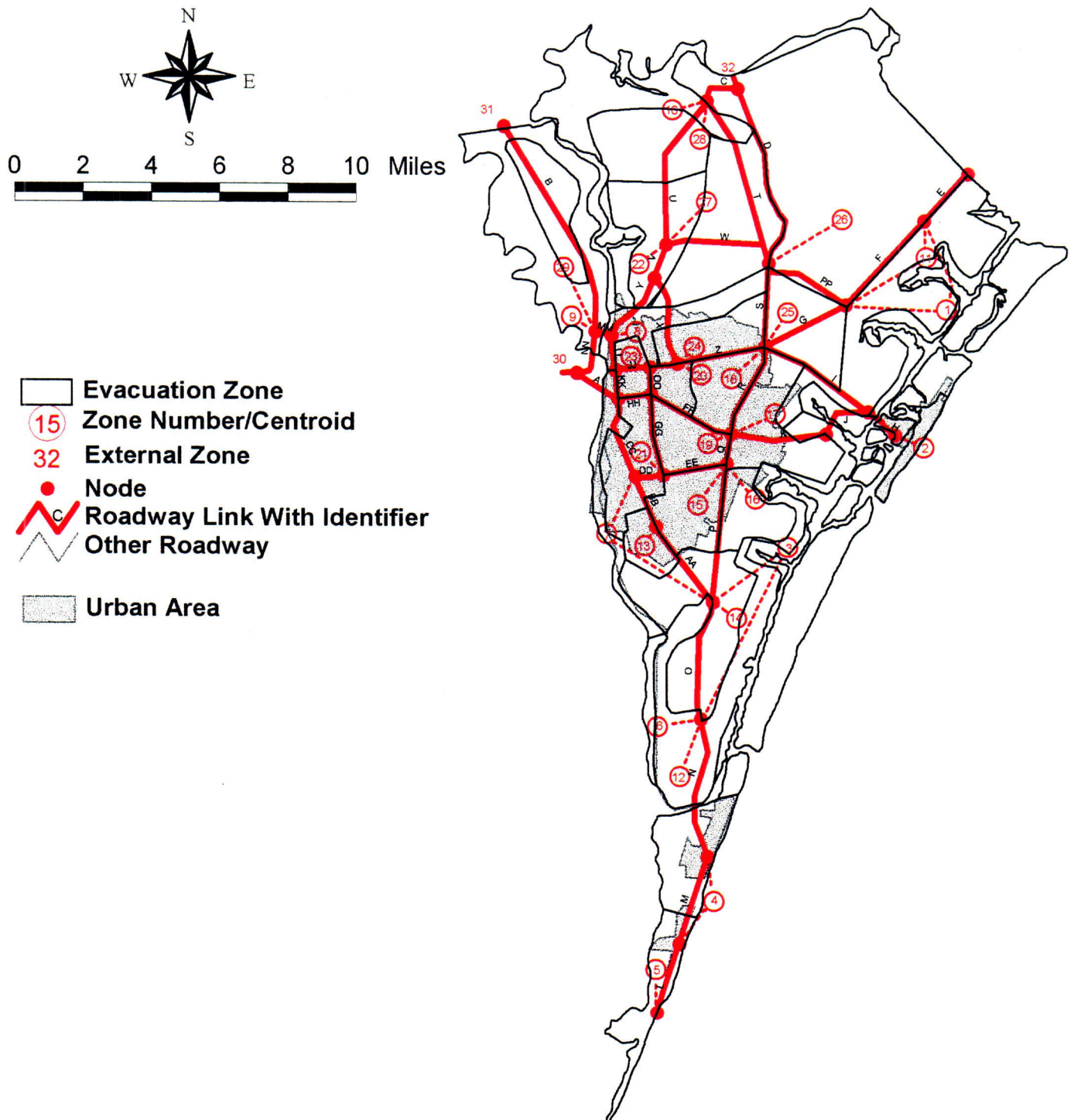
Evacuation Road Network



Brunswick County

North Carolina Hurricane Evacuation Restudy

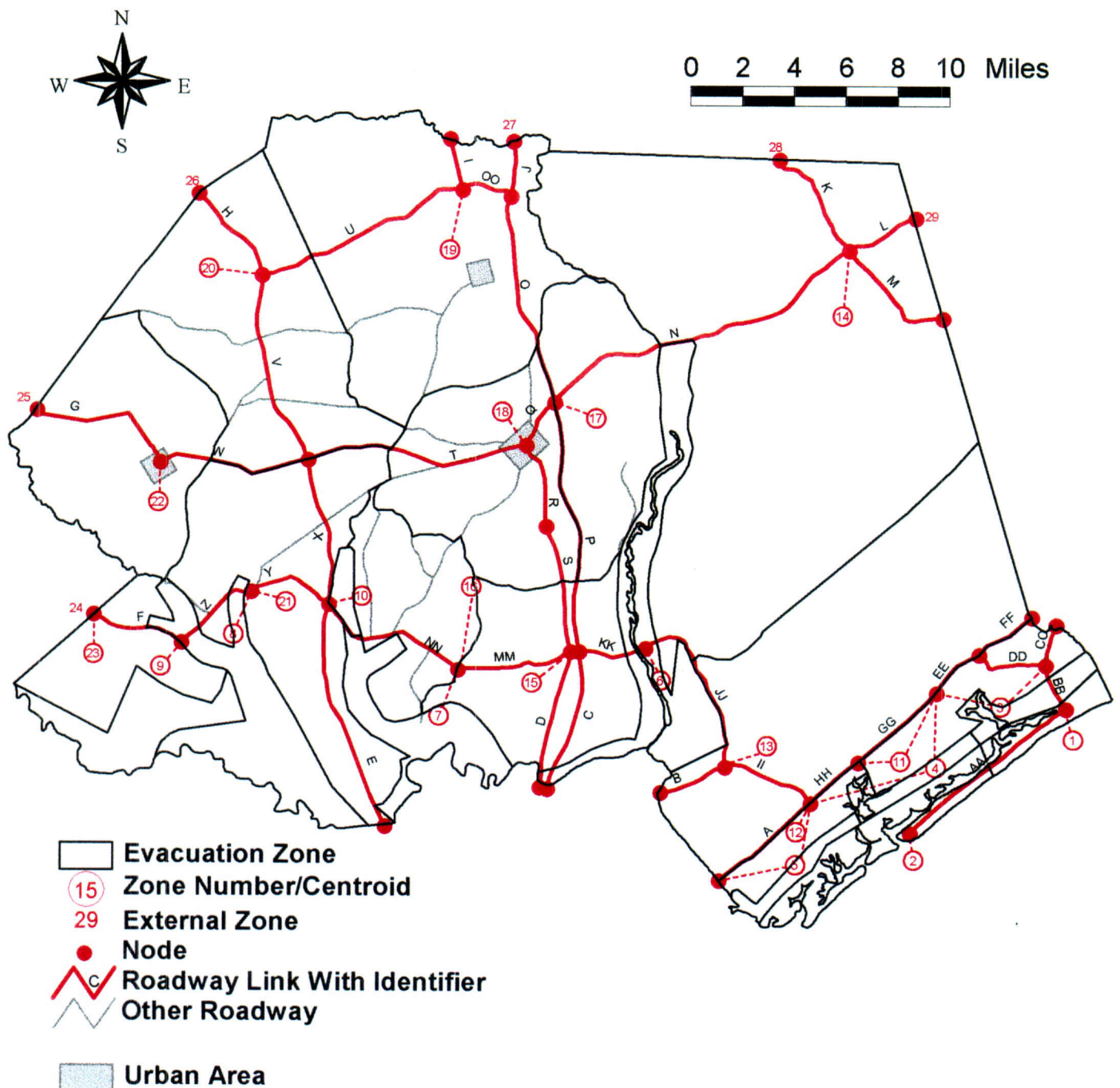
Figure 2-19 Evacuation Road Network



New Hanover County

North Carolina Hurricane Evacuation Restudy

Figure 2-20 Evacuation Road Network

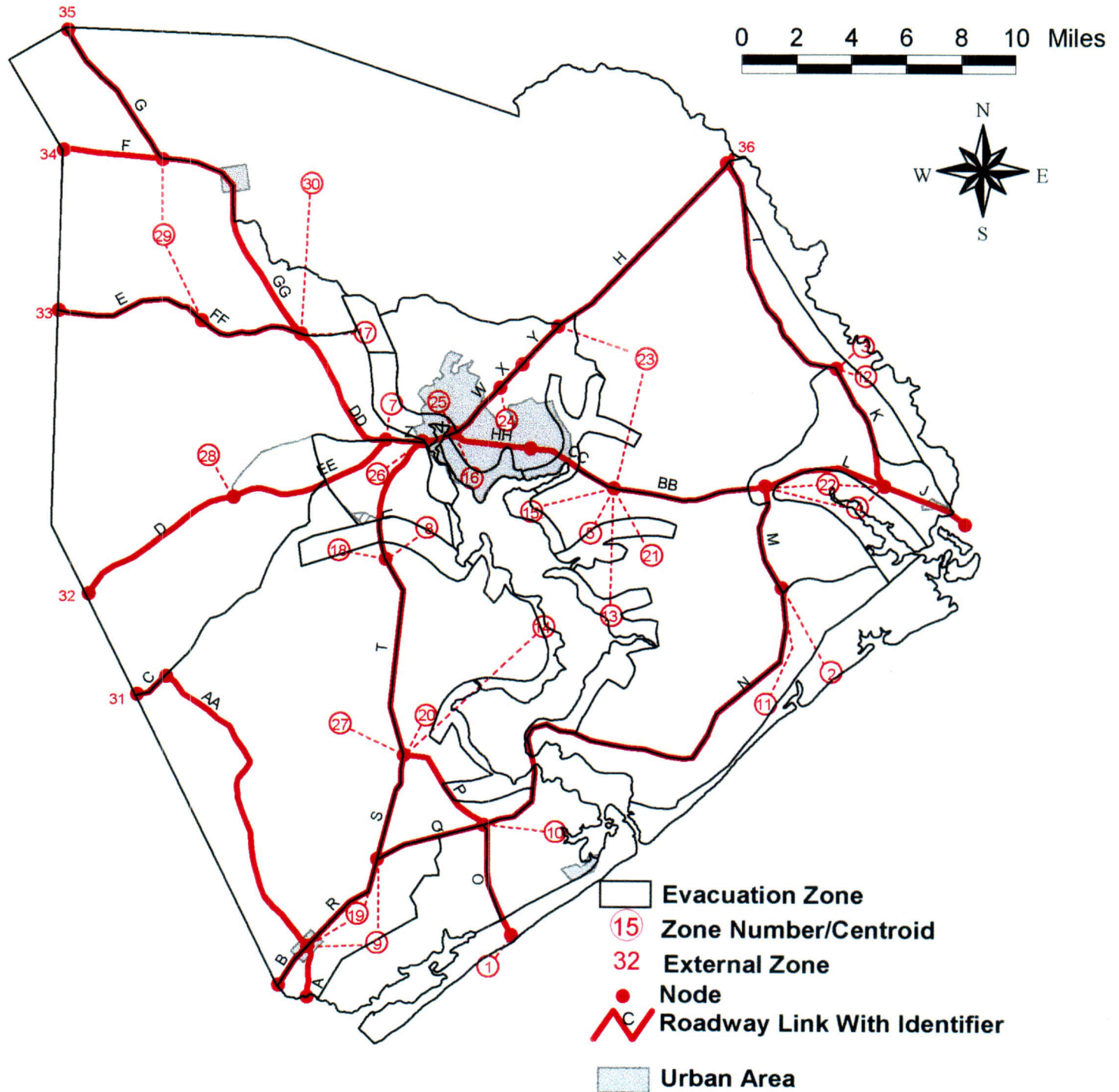


Pender County

North Carolina Hurricane Evacuation Restudy

Figure 2-21

Evacuation Road Network

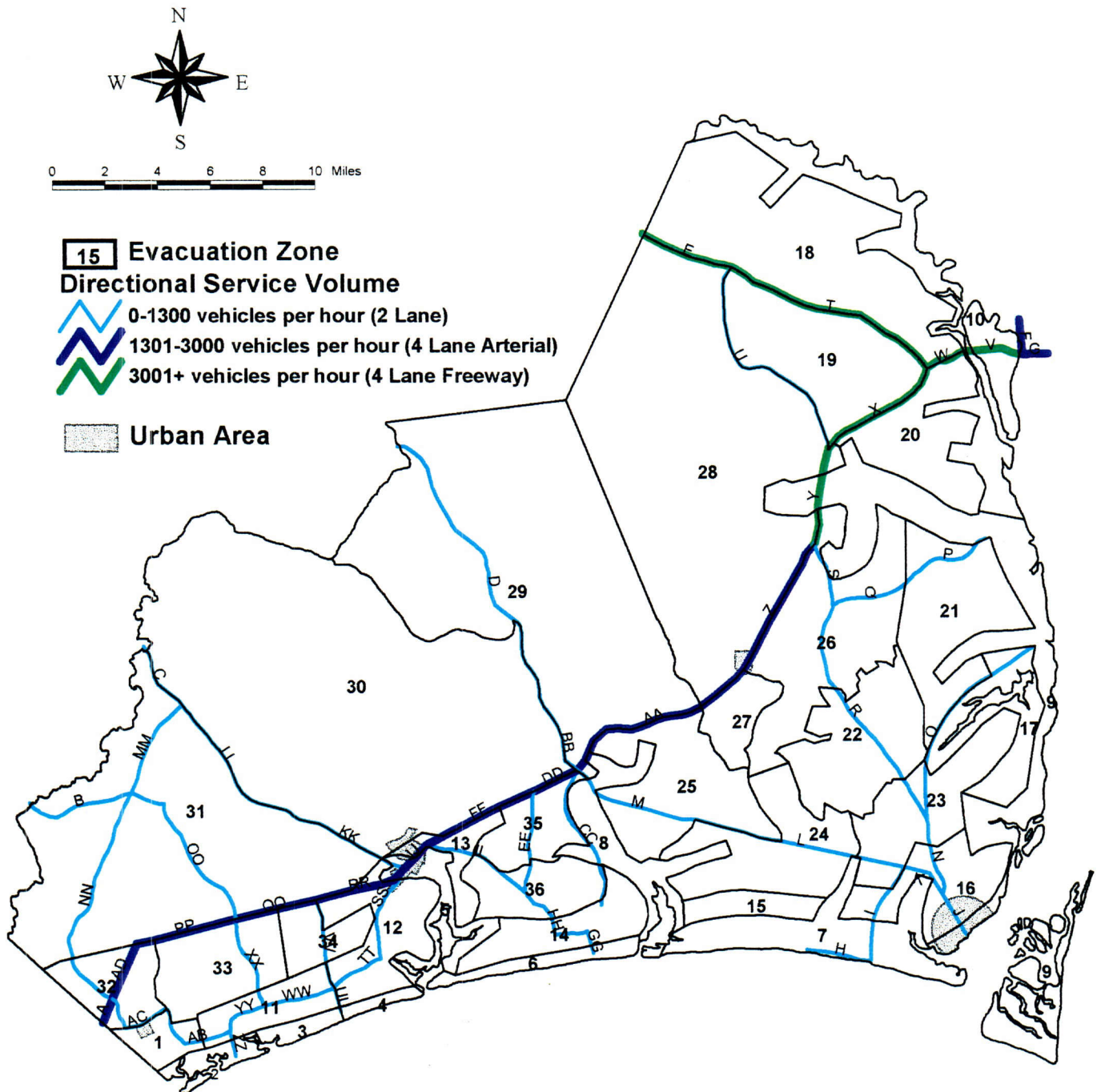


Onslow County

North Carolina Hurricane Evacuation Restudy

Figure 2-22

1996 Directional Service Volumes

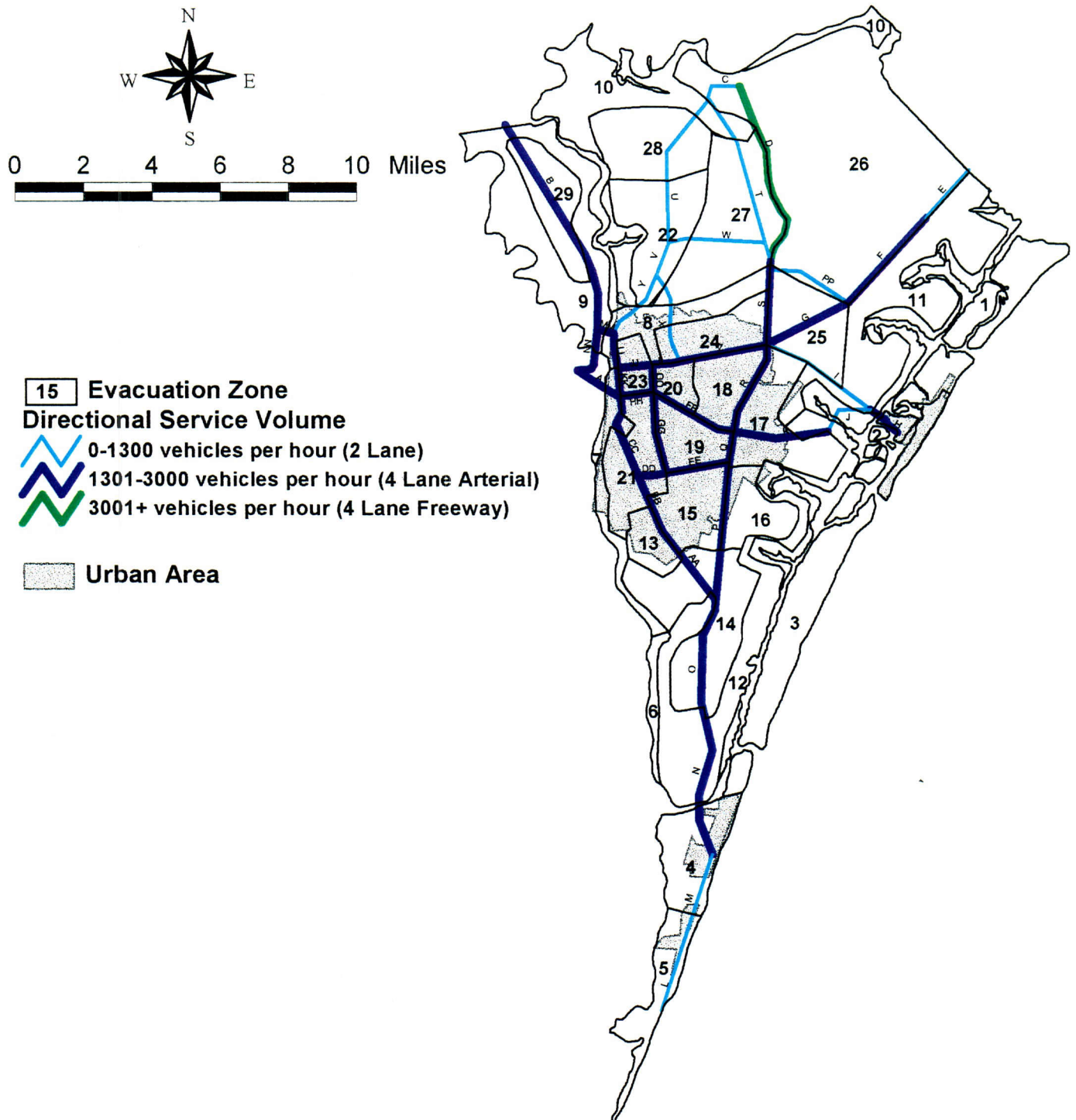


Brunswick County

North Carolina Hurricane Evacuation Restudy

Figure 2-23

1996 Directional Service Volumes

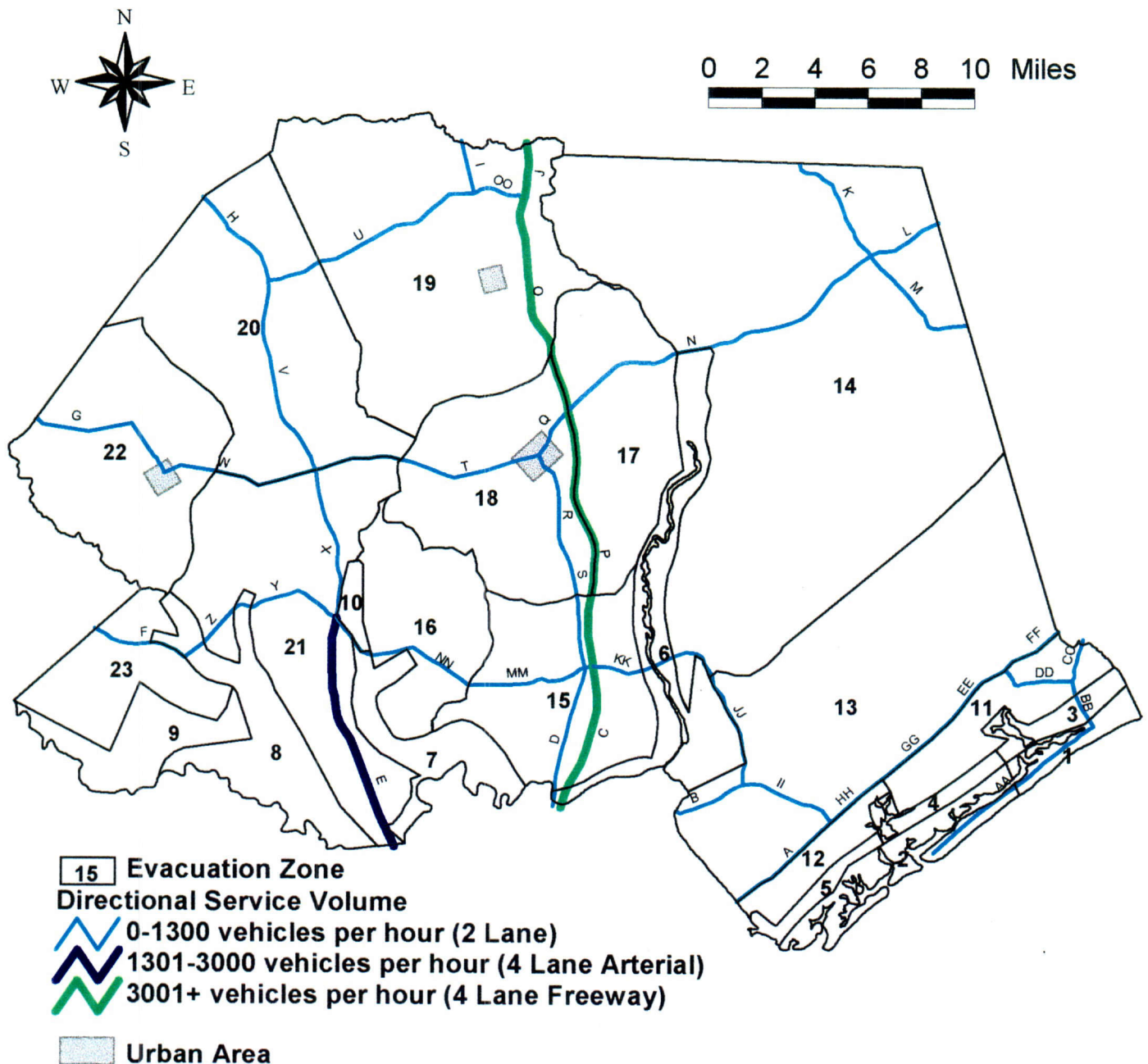


New Hanover County

North Carolina Hurricane Evacuation Restudy

Figure 2-24

1996 Directional Service Volumes

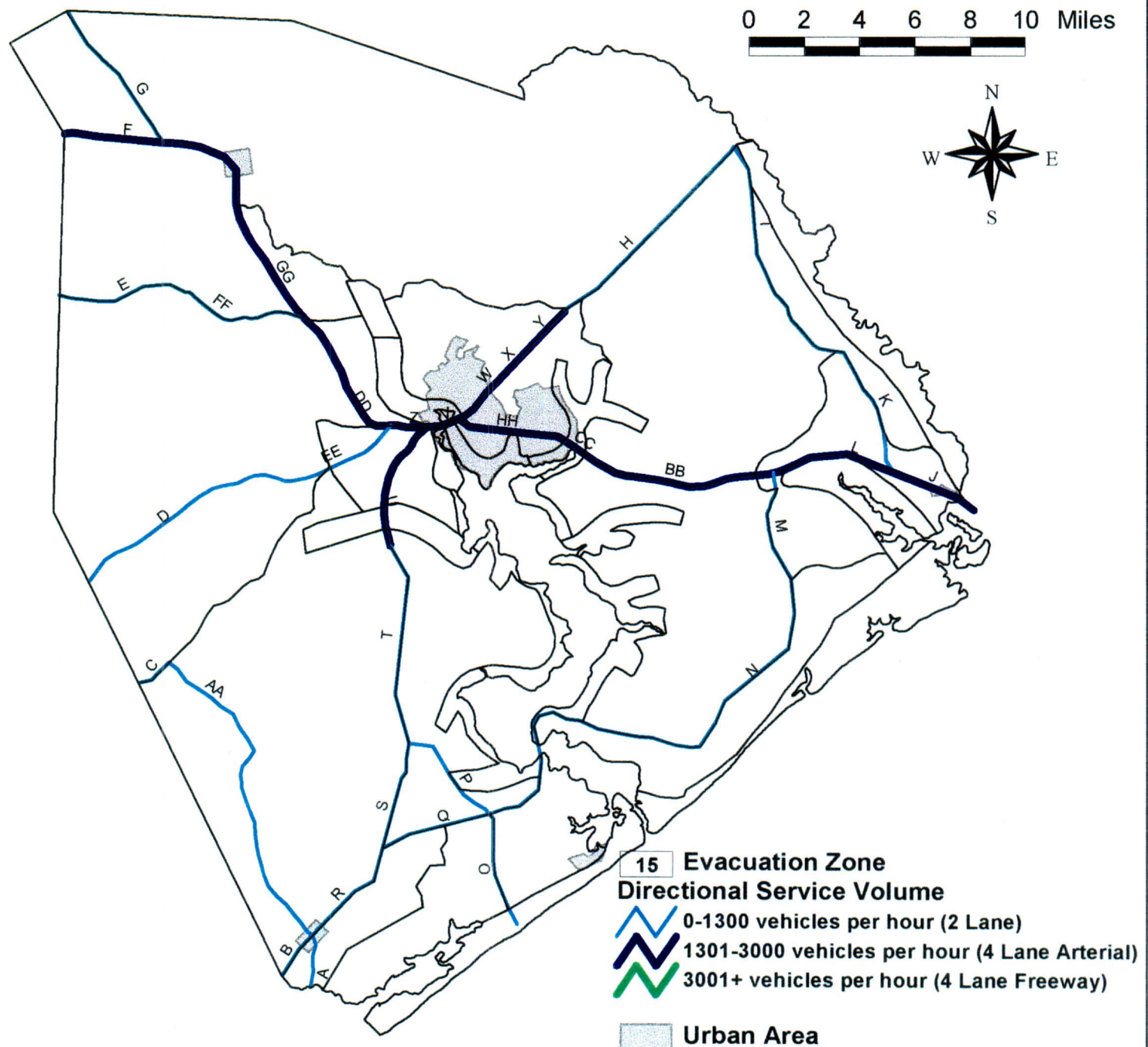


Pender County

North Carolina Hurricane Evacuation Restudy

Figure 2-25

1996 Directional Service Volumes



Onslow County

North Carolina Hurricane Evacuation Restudy

3.0 EVACUATION CLEARANCE TIME MODEL APPLICATION/SYSTEM FORECASTS

Application of PBS&J's transportation modeling methodology for hurricane evacuations, using inputs and assumptions discussed in Chapter 2, produced several key data items and forecasts for hurricane evacuation planning and preparedness. Completion of the transportation modeling for the 1996 base year produced the following:

- Evacuating people and vehicle statistics by evacuation zone by storm scenario
- Shelter demand and capacity considerations by scenario
- Traffic volumes and critical roadway segments by scenario
- Estimated clearance times by scenario

Although a wealth of data is produced in the transportation analysis (as provided in the Transportation Model Support Document Appendix), the items listed above are the most critical outputs for planning for shelter needs, anticipating bottlenecks, and defining the timing requirements of an evacuation.

3.1 CLEARANCE TIME MODEL DESCRIPTION

The general philosophy supporting all of PBS&J's hurricane evacuation clearance time work around the country is that the analysis must be sophisticated enough to produce reliable estimates of hurricane evacuation clearance time, yet simple enough for the emergency management community to be able to review key modeling assumptions and products. This section provides a brief overview of the analysis steps and description of the computer program framework for accomplishing the

modeling steps. The key steps are as follows:

- ~ Development of Evacuation Zones and Data - identifies who is vulnerable
- ~ Trip Generation - calculates how many evacuees by county sub area for a particular scenario
- ~ Trip Distribution - determines where evacuees will go
- ~ Development of Evacuation Road Network - addresses what are the roads that can be used for evacuation and what is the carrying capacity
- ~ Trip Assignment - determines what route(s) evacuees will take to get from their origin to their destination.
- ~ Calculation of Clearance Time - determines how much time it will take for all evacuees to clear the evacuation network.

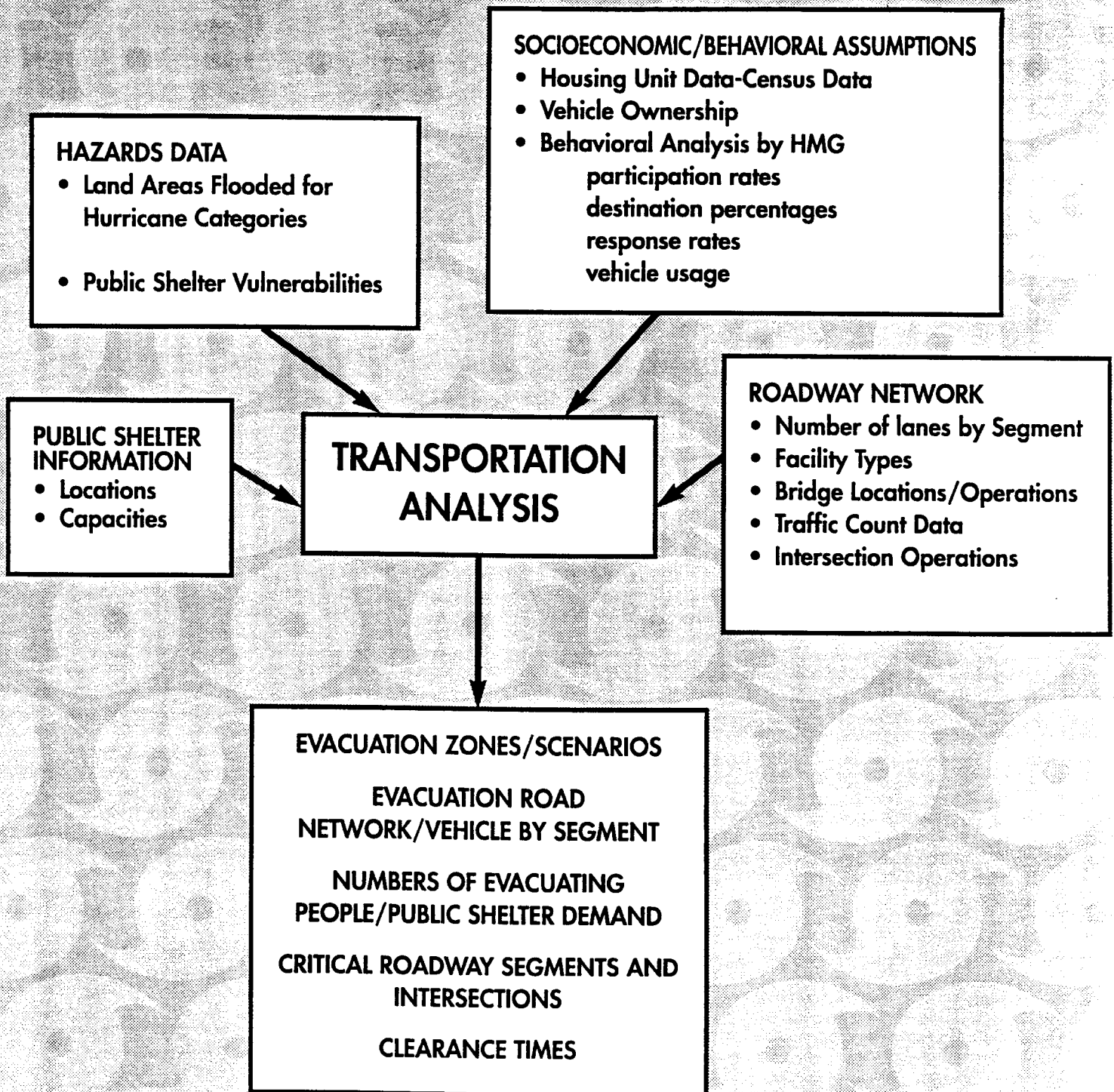
Figure 3-1 illustrates the major inputs and outputs of this process. PBS&J developed an in-house set of computer programs to facilitate the transportation modeling work steps described above. Programs are in a Lotus for Windows environment and were developed in late 1993/early 1994 by PBS&J for all of the firm's ongoing hurricane work. The programs are user friendly in terms of pulldown menus and diagnostic aids.

The Transportation Model Support Document appendix to this report provides details about workings of the model, file nomenclature and management, and model application. One of the great benefits of operating in the Lotus environment for this study was the ability to import data files directly into the initial programs. Likewise output of later programs was able to be captured and easily exported to GIS for displays and mapping. The use of GIS greatly enhanced the quality of technical data development and documentation.

3.2 EVACUATING PEOPLE AND VEHICLES BY SCENARIO

Using the trip generation module of PBS&J's battery of hurricane programs, total evacuating people and vehicles produced by each evacuation zone were calculated and split by general destination type

TRANSPORTATION ANALYSIS OVERVIEW



(trip purpose). The four general destination types are in-county public shelter, in-county hotel/motels, in-county home of a friend or relative, and out-of-county. This was accomplished for the 1996 base year, for each storm intensity and for two levels of assumed tourist occupancy.

Table 3-1 shows the numbers of people estimated to leave dwelling units for each county and scenario. Numbers of people involved in an actual evacuation will most likely be less than these figures because 100 percent participation of units in storm surge vulnerable evacuated areas and all mobile homes was assumed. Even with door-to-door evacuation notification, it will be difficult to convince all to leave who should leave.

Figures 3-2 through 3-9 graphically show ranges of evacuating population by county by evacuation zone for the storm and tourist occupancy scenarios.

3.3 PUBLIC SHELTER DEMAND/CAPACITY CONSIDERATIONS

In terms of public shelter demand and available capacity, except for Brunswick County, each county could use more in-county public shelter space for the higher categories of hurricanes. The public shelter list provided to PBS&J for each county included shelter locations and capacities. The capacities were considerably less than what was shown in the 1986 Corps hurricane study. Table 3-1 shows potential public shelter demand and reported capacities. In the transportation analysis, after public shelters were filled even beyond the theoretical capacity, the remaining public shelter demand were distributed to in-county evacuation destination zones similar to the friends/relative trip type. Local churches and other civic groups may help with public sheltering needs.

Figures 3-10 through 3-17 illustrate the range of 1996 public shelter demand by evacuation zone for the storm scenarios. As the counties approach the year 2000, the need for in-county public shelter space could be even greater, particularly if growth in mobile homes continues.

Table 3-1

**1996 EVACUATING PEOPLE STATISTICS BY COUNTY
AND STORM SCENARIO
North Carolina Hurricane Evacuation Restudy**

Brunswick County

	<u>Maximum Evacuating Population/Public Shelter Demand</u>		
	Low Tourist <u>Occupancy</u>	Medium Tourist <u>Occupancy</u>	High Tourist <u>Occupancy</u>
Category 1-2 Hurricane	38,850/4,450 people	49,600/4,990	61,880/5,600
Category 3-5 Hurricane	49,070/7,030 people	62,870/7,720	78,640/8,500
Low Tourist Occupancy = 15%			Public Shelter Capacity - 10,503
Medium Tourist Occupancy = 50%			
High Tourist Occupancy = 90%			

New Hanover County

	<u>Maximum Evacuating Population/Public Shelter Demand</u>	
	Low Tourist <u>Occupancy</u>	High Tourist <u>Occupancy</u>
Category 1-3 Hurricane	41,300/3,800 people	45,200/3,960
Category 4-5 Hurricane	56,900/7,400 people	61,100/7,650
Low Tourist Occupancy = 50%		Public Shelter Capacity - 1,550
High Tourist Occupancy = 90%		

Pender County

	<u>Maximum Evacuating Population/Public Shelter Demand</u>	
	Low Tourist <u>Occupancy</u>	High Tourist <u>Occupancy</u>
Category 1-2 Hurricane	19,600/2,500 people	21,900/2,600
Category 3-5 Hurricane	22,100/3,400 people	24,860/3,550
Low Tourist Occupancy = 50%		Public Shelter Capacity - 1,633
High Tourist Occupancy = 90%		

Onslow County

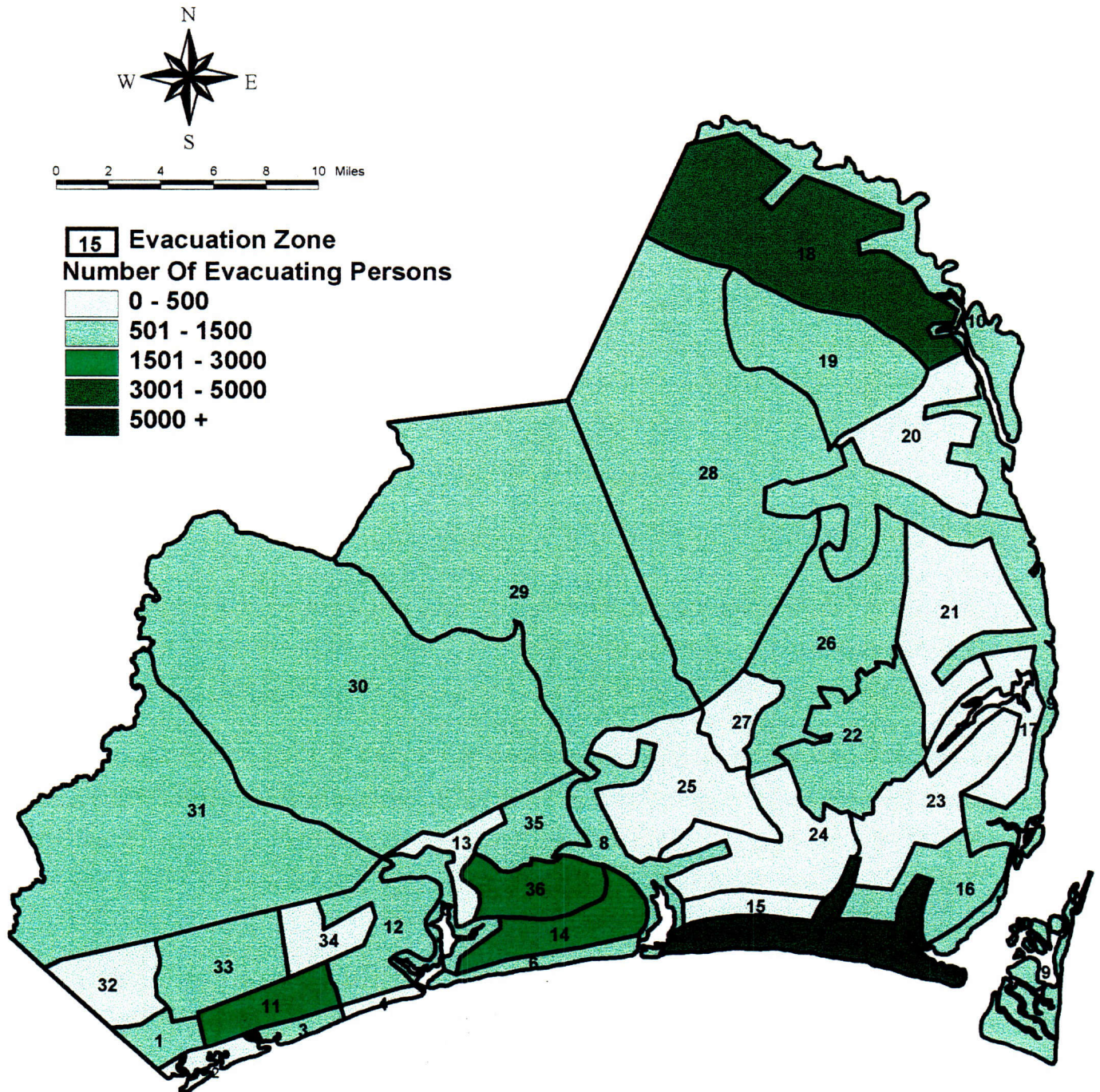
	<u>Maximum Evacuating Population/Public Shelter Demand</u>	
	Low Tourist <u>Occupancy</u>	High Tourist <u>Occupancy</u>
Category 1-2 Hurricane	49,200/7,600 people	50,800/7,700
Category 3-5 Hurricane	63,370/12,100 people	65,190/12,240
Low Tourist Occupancy = 50%		Public Shelter Capacity - 1,893
High Tourist Occupancy = 90%		

NOTE: Each scenario includes 100% of the population in the surge area plus all mobile homes plus a small percentage of the theoretically "non-vulnerable" population for each scenario.

Figure 3-2

Evacuating Population

Category 1-2 Hurricane
Low Tourist Occupancy



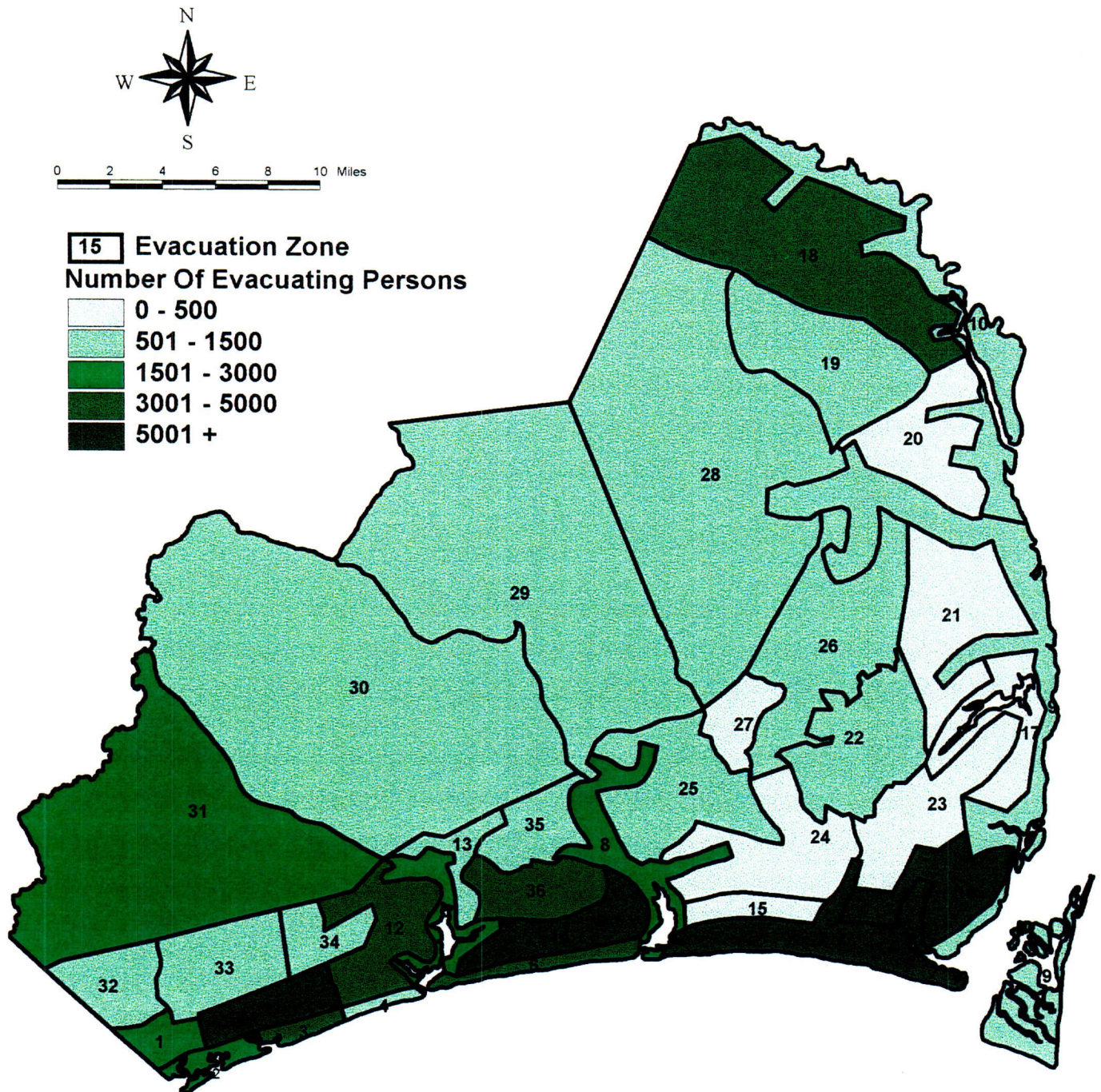
Brunswick County

North Carolina Hurricane Evacuation Restudy

Figure 3-3

Evacuating Population

Category 3-5 Hurricane
High Tourist Occupancy



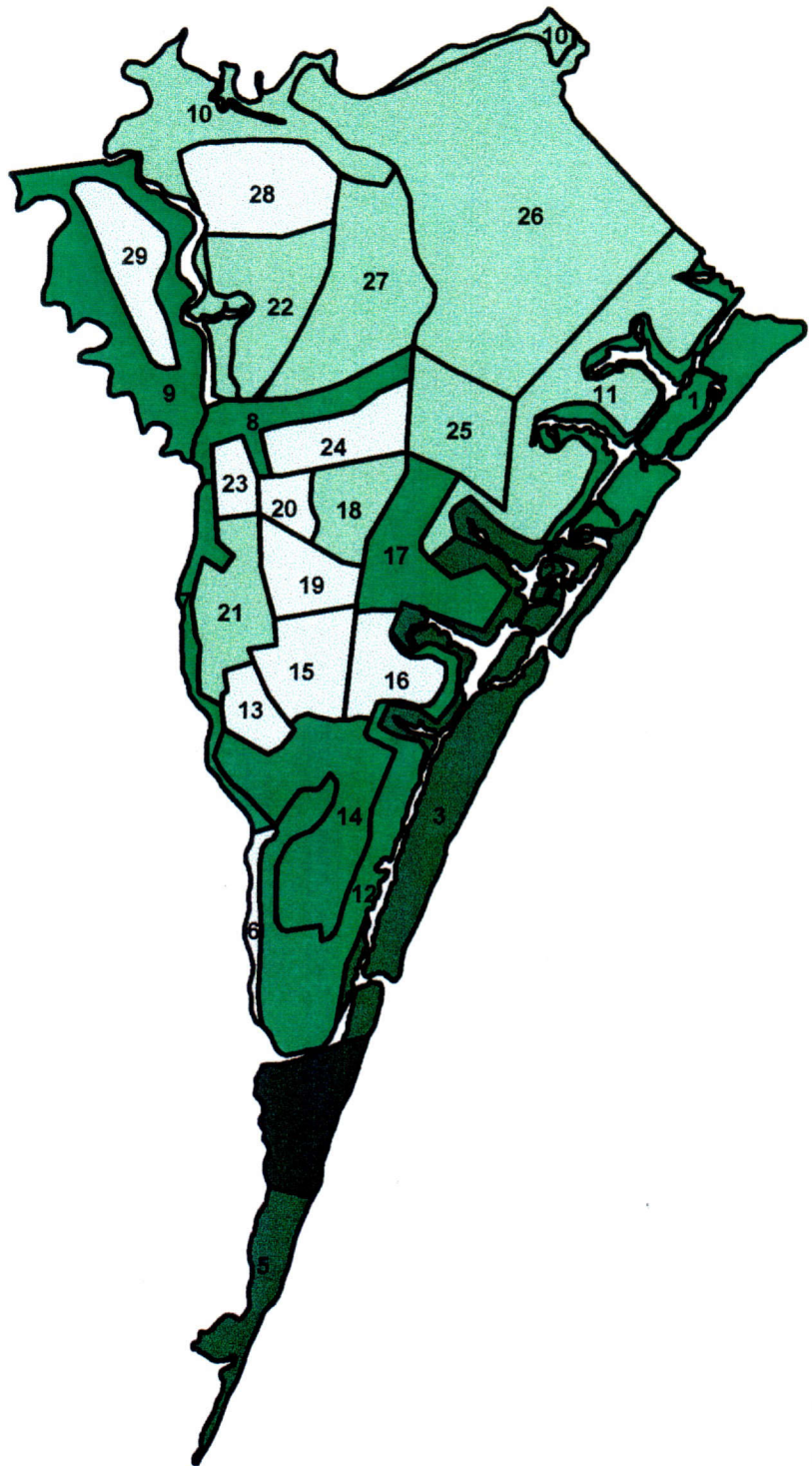
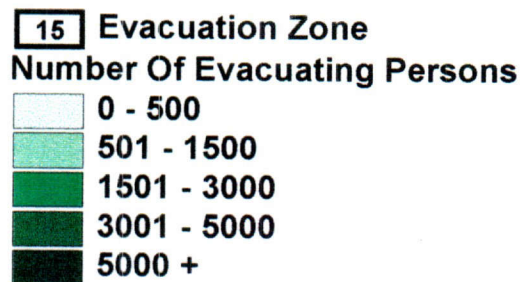
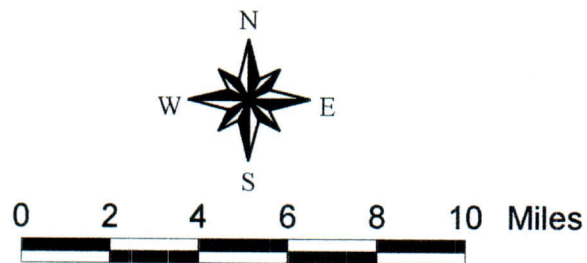
Brunswick County

North Carolina Hurricane Evacuation Restudy

Figure 3-4

Evacuating Population

Category 1-3 Hurricane
Low Tourist Occupancy



New Hanover County

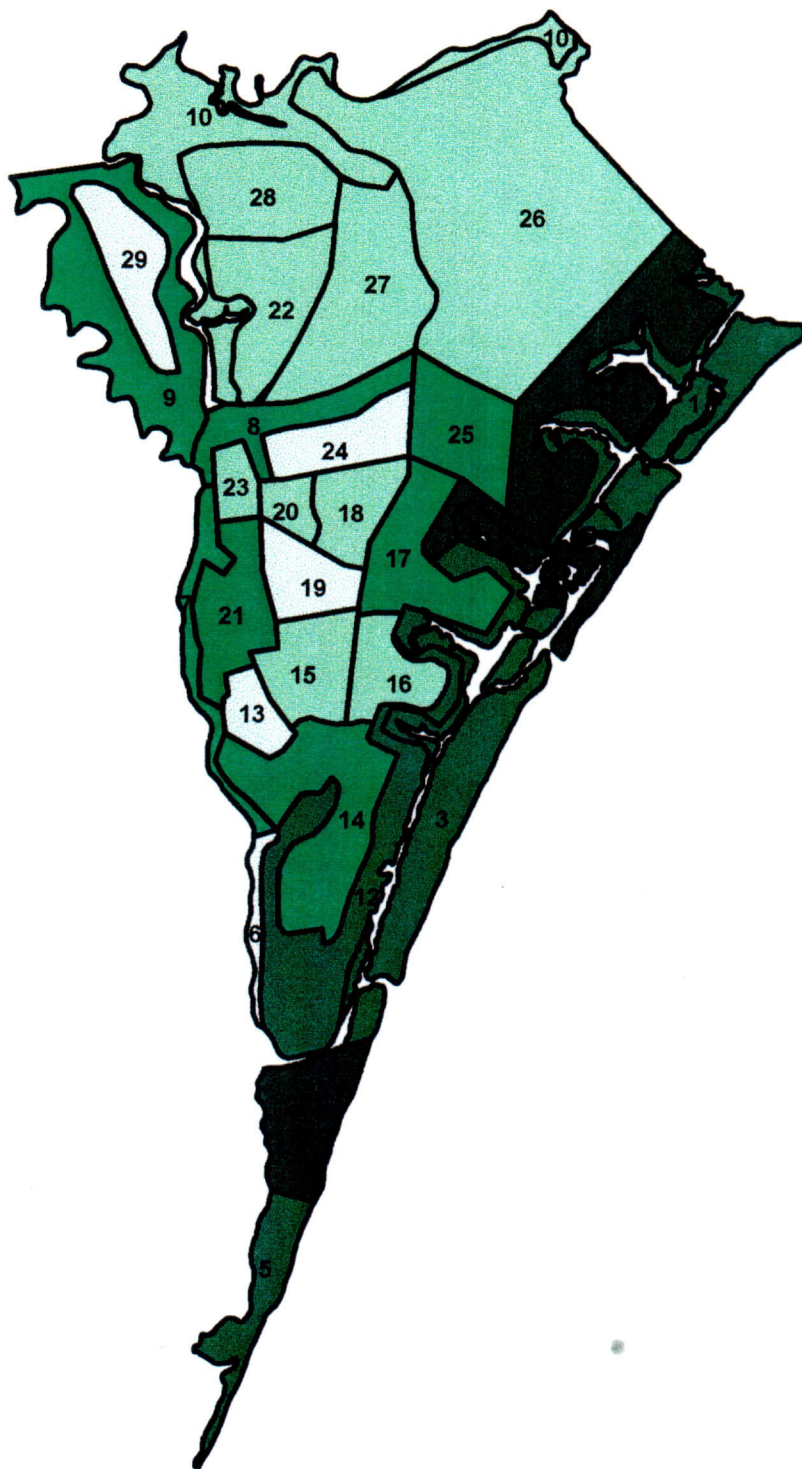
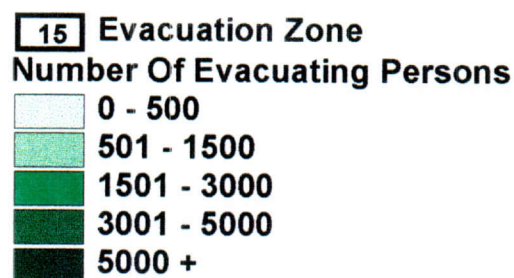
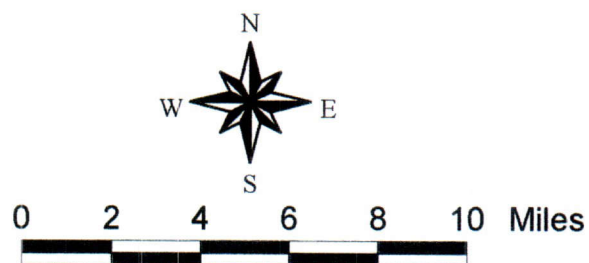
North Carolina Hurricane Evacuation Restudy

Figure 3-5

Evacuating Population

Category 4-5 Hurricane

High Tourist Occupancy



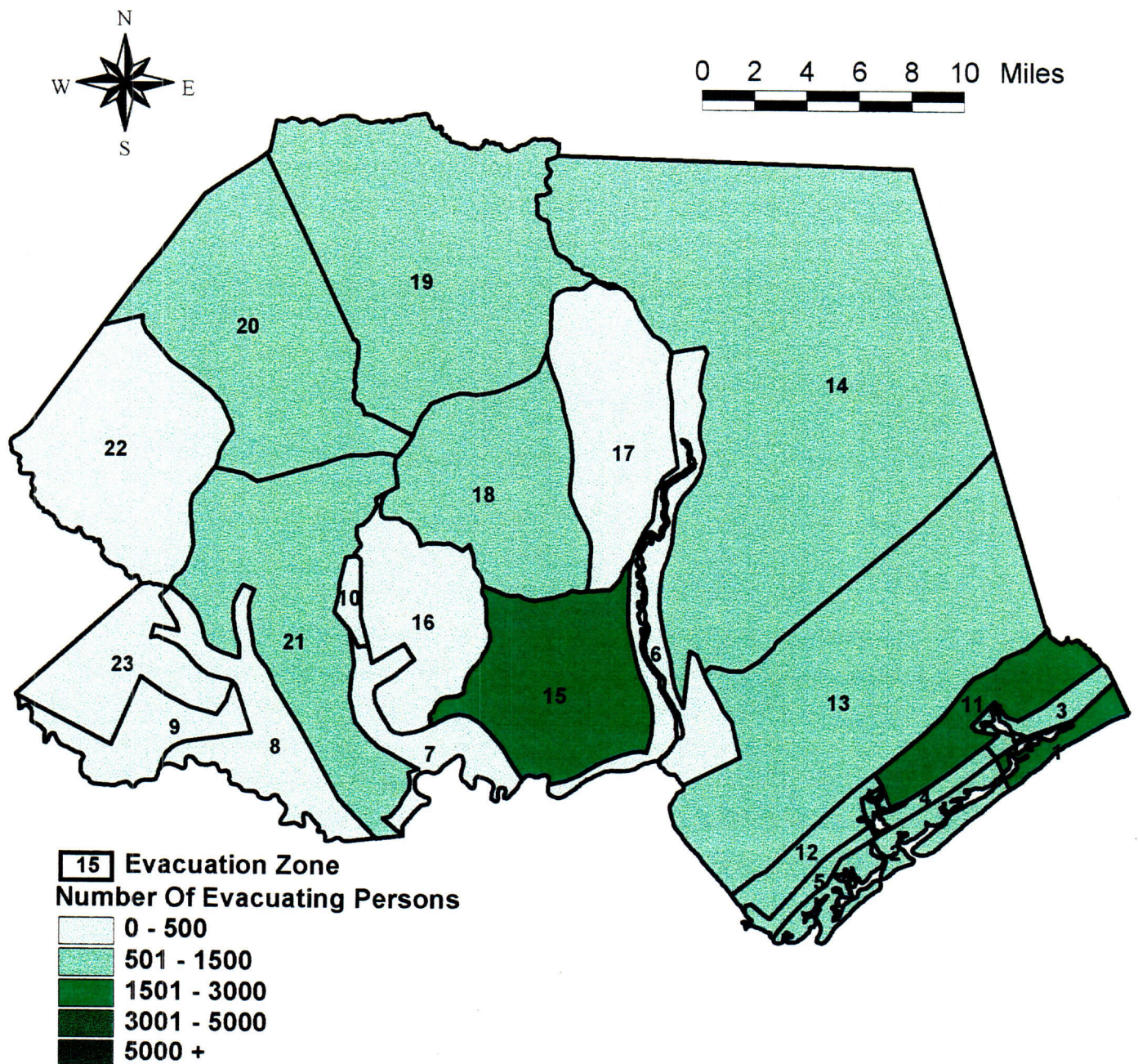
New Hanover County

North Carolina Hurricane Evacuation Restudy

Figure 3-6

Evacuating Population

Category 1-2 Hurricane
Low Tourist Occupancy



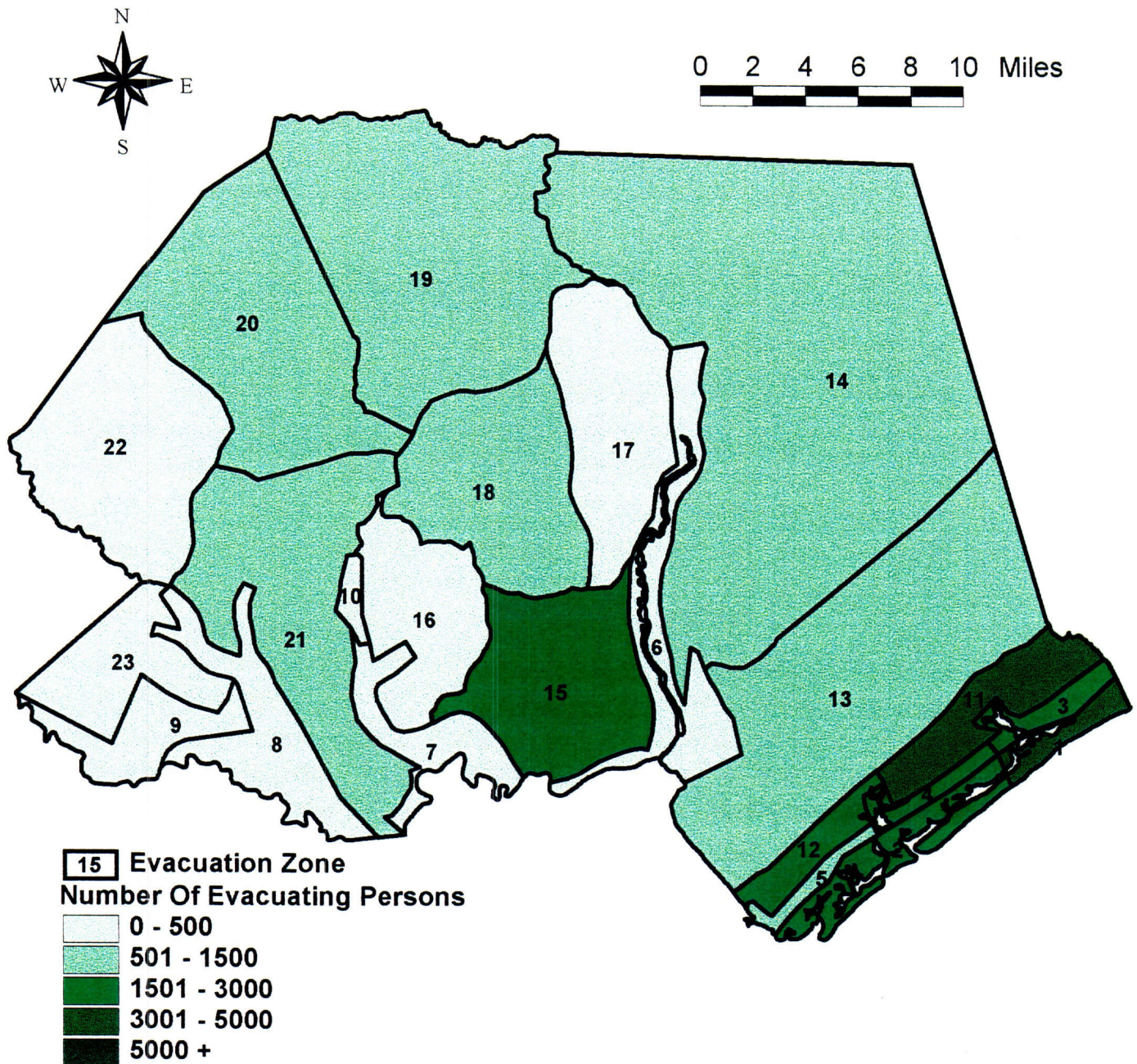
Pender County

North Carolina Hurricane Evacuation Restudy

Figure 3-7

Evacuating Population

Category 3-5 Hurricane
High Tourist Occupancy



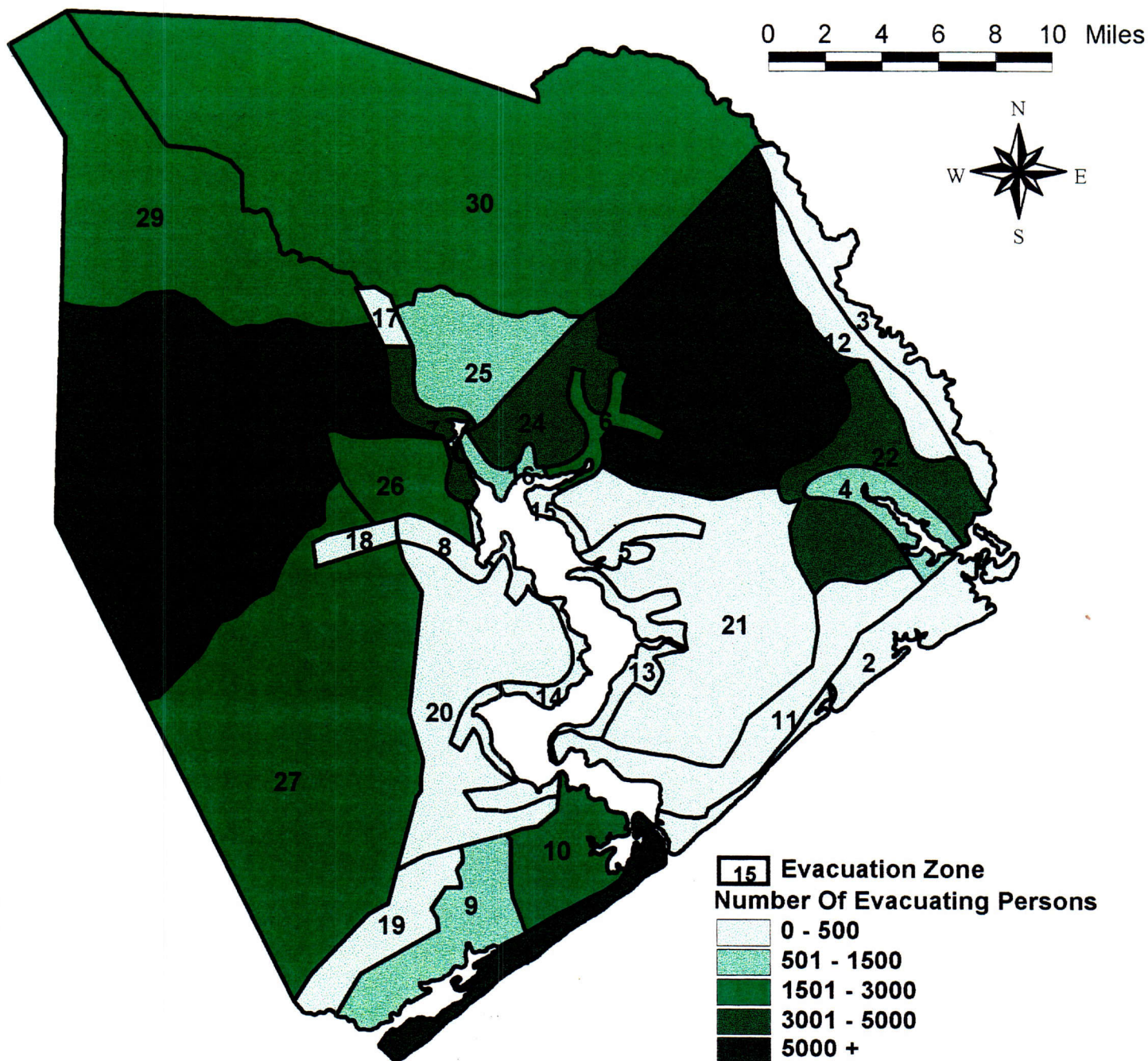
Pender County

North Carolina Hurricane Evacuation Restudy

Figure 3-8

Evacuating Population

Category 1-2 Hurricane
Low Tourist Occupancy



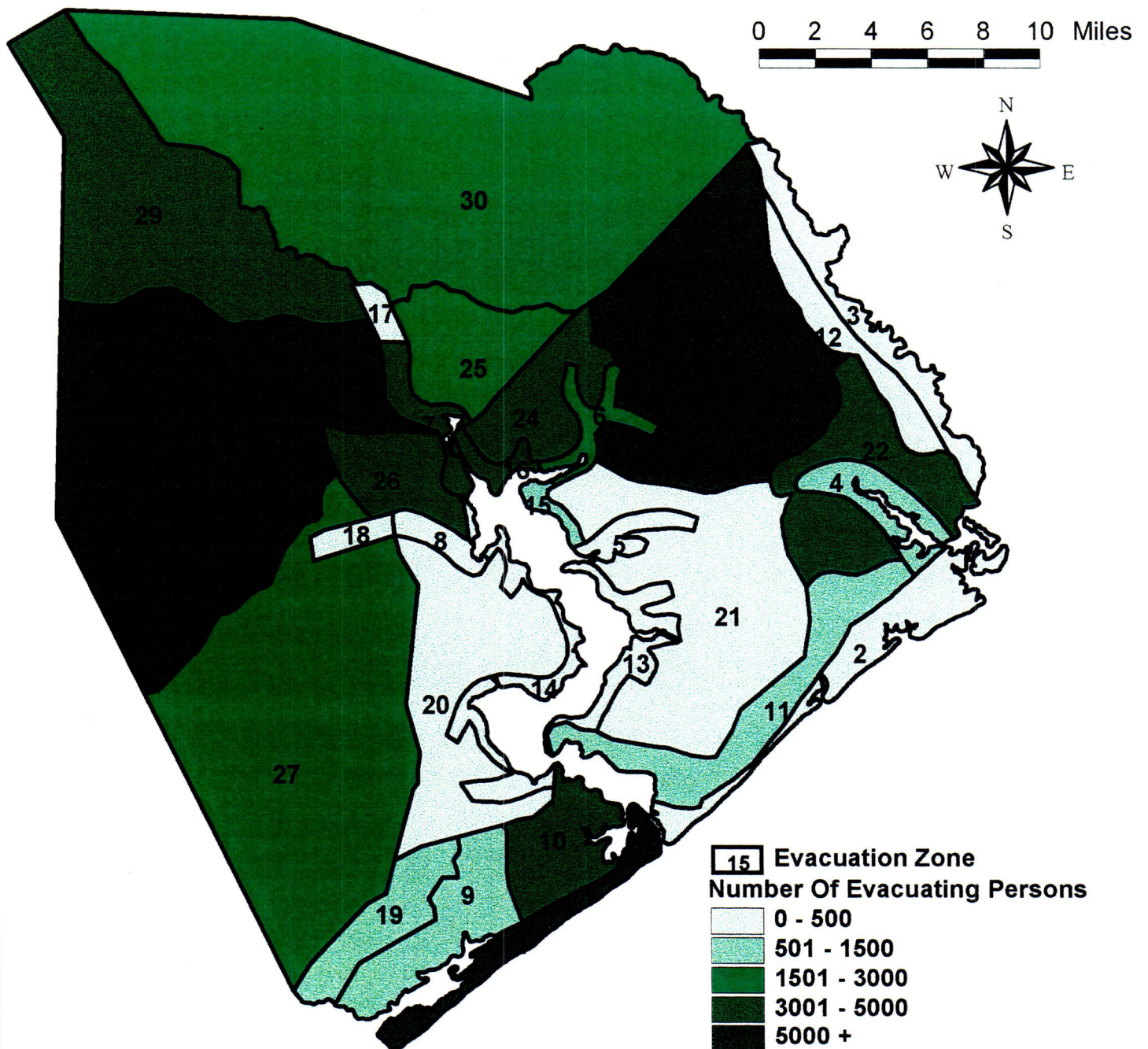
Onslow County

North Carolina Hurricane Evacuation Restudy

Figure 3-9

Evacuating Population

Category 3-5 Hurricane
High Tourist Occupancy



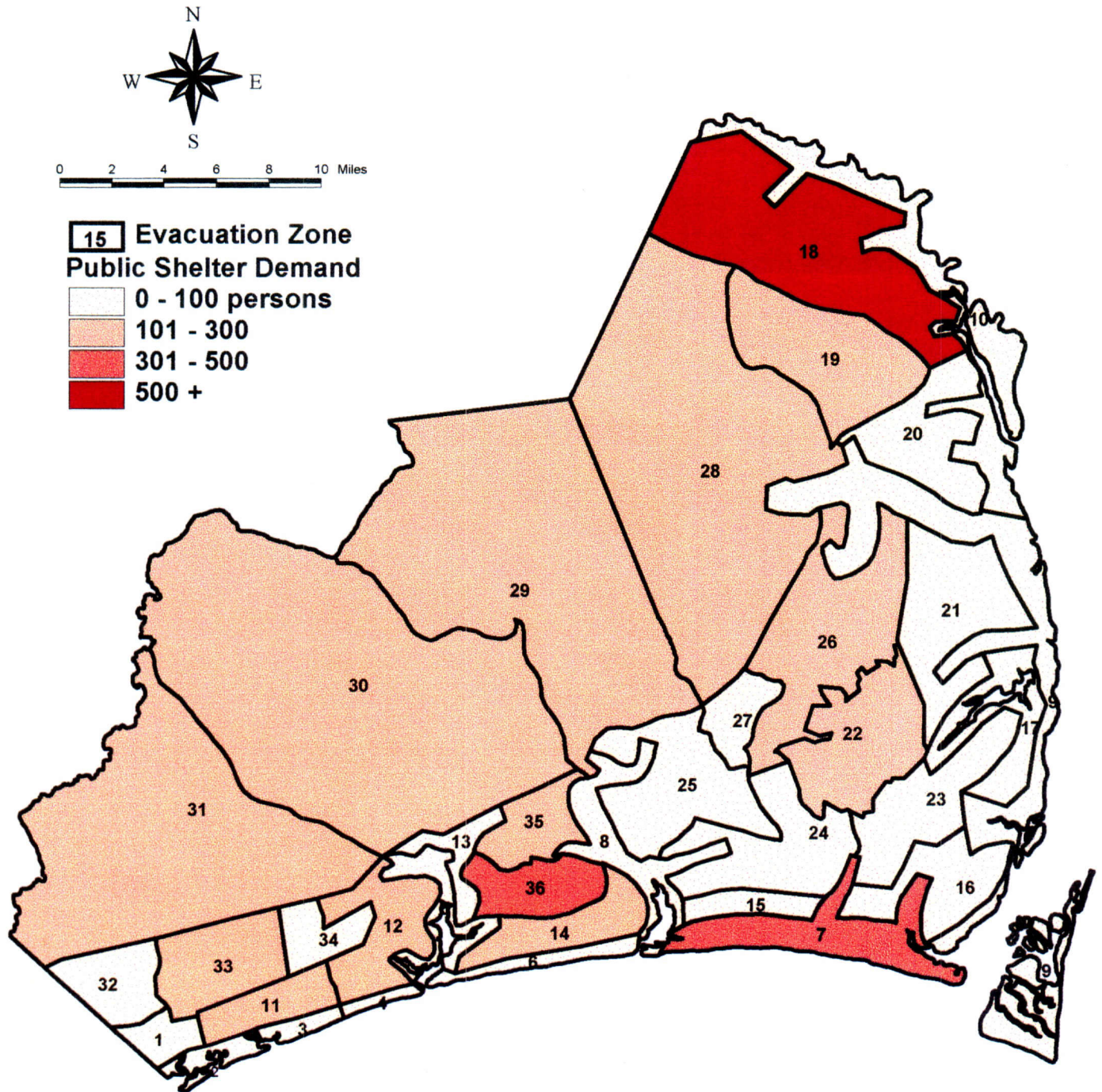
Onslow County

North Carolina Hurricane Evacuation Restudy

Figure 3-10

Public Shelter Demand

Category 1-2 Hurricane
Low Tourist Occupancy



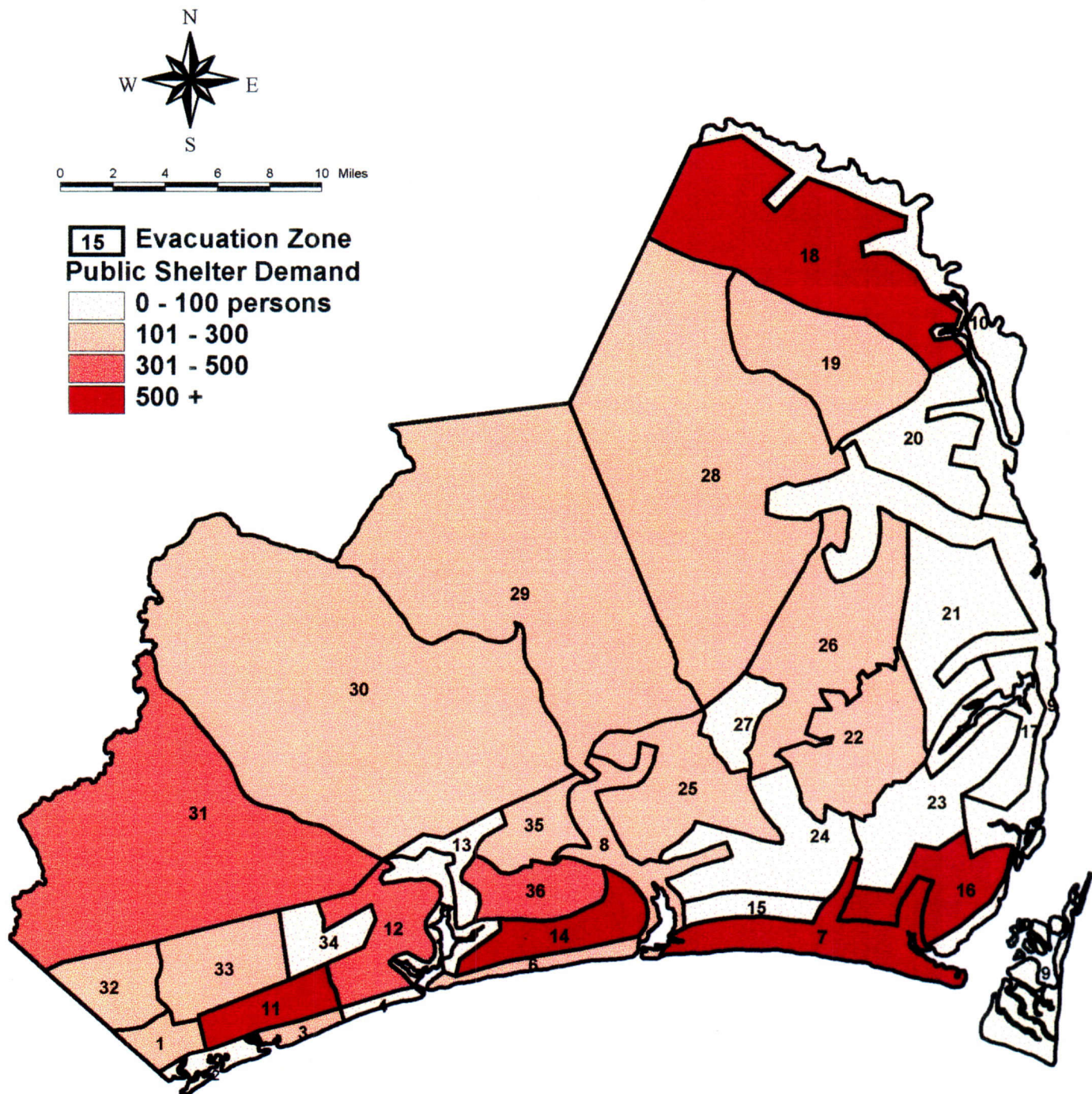
Brunswick County

North Carolina Hurricane Evacuation Restudy

Figure 3-11

Public Shelter Demand

Category 3-5 Hurricane
High Tourist Occupancy



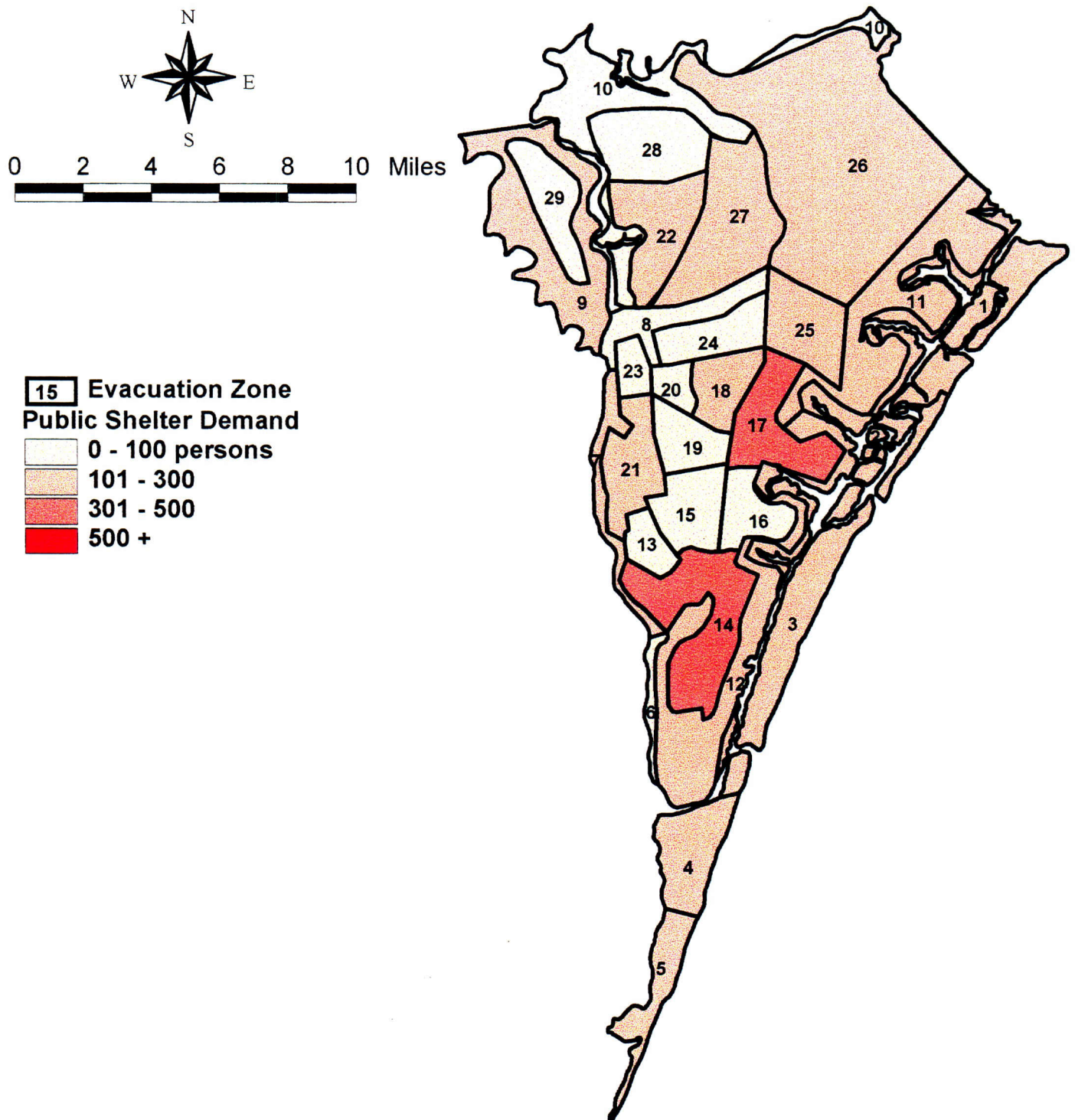
Brunswick County

North Carolina Hurricane Evacuation Restudy

Figure 3-12

Public Shelter Demand

Category 1-3 Hurricane
Low Tourist Occupancy



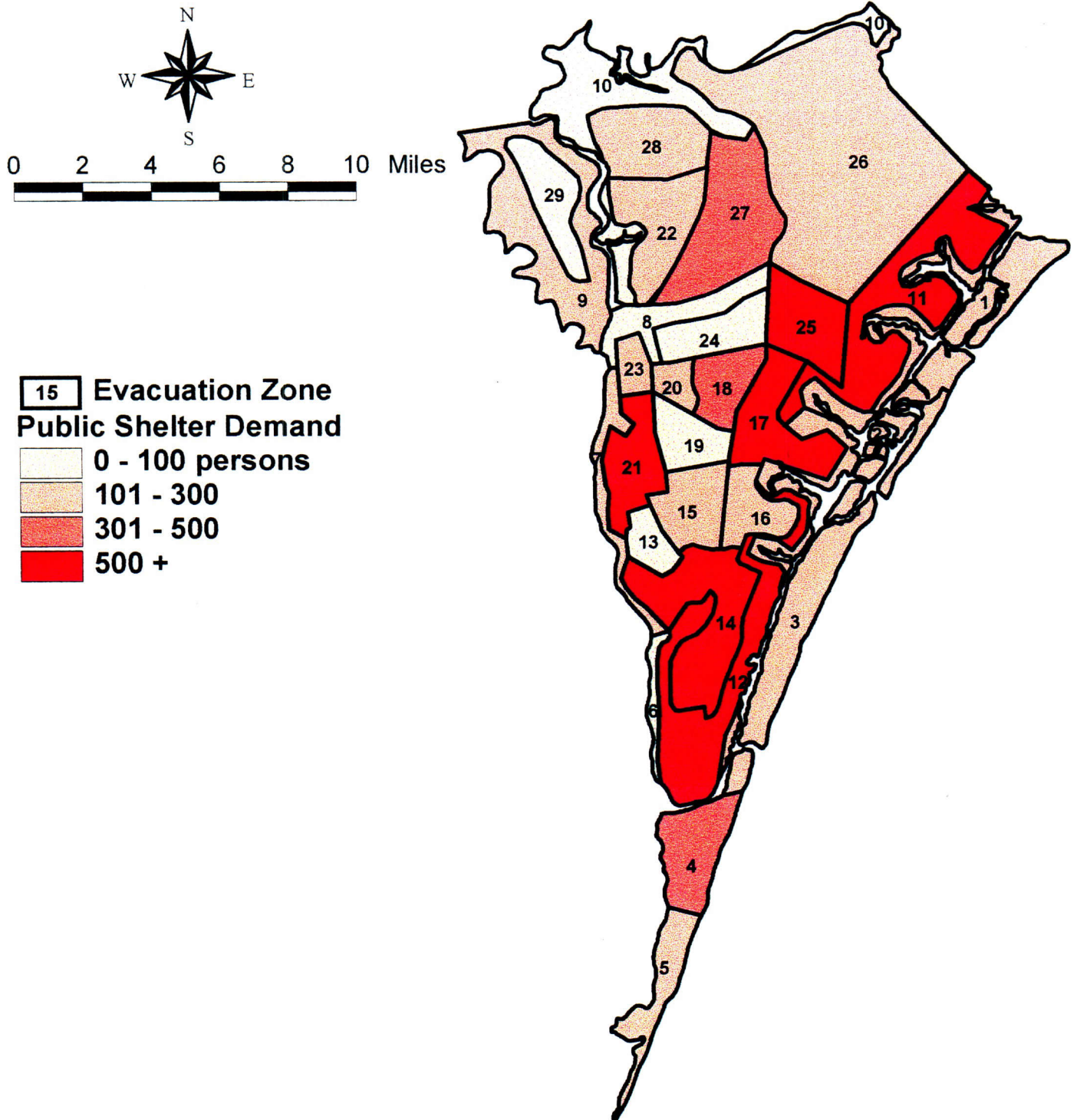
New Hanover County

North Carolina Hurricane Evacuation Restudy

Figure 3-13

Public Shelter Demand

Category 4-5 Hurricane
High Tourist Occupancy



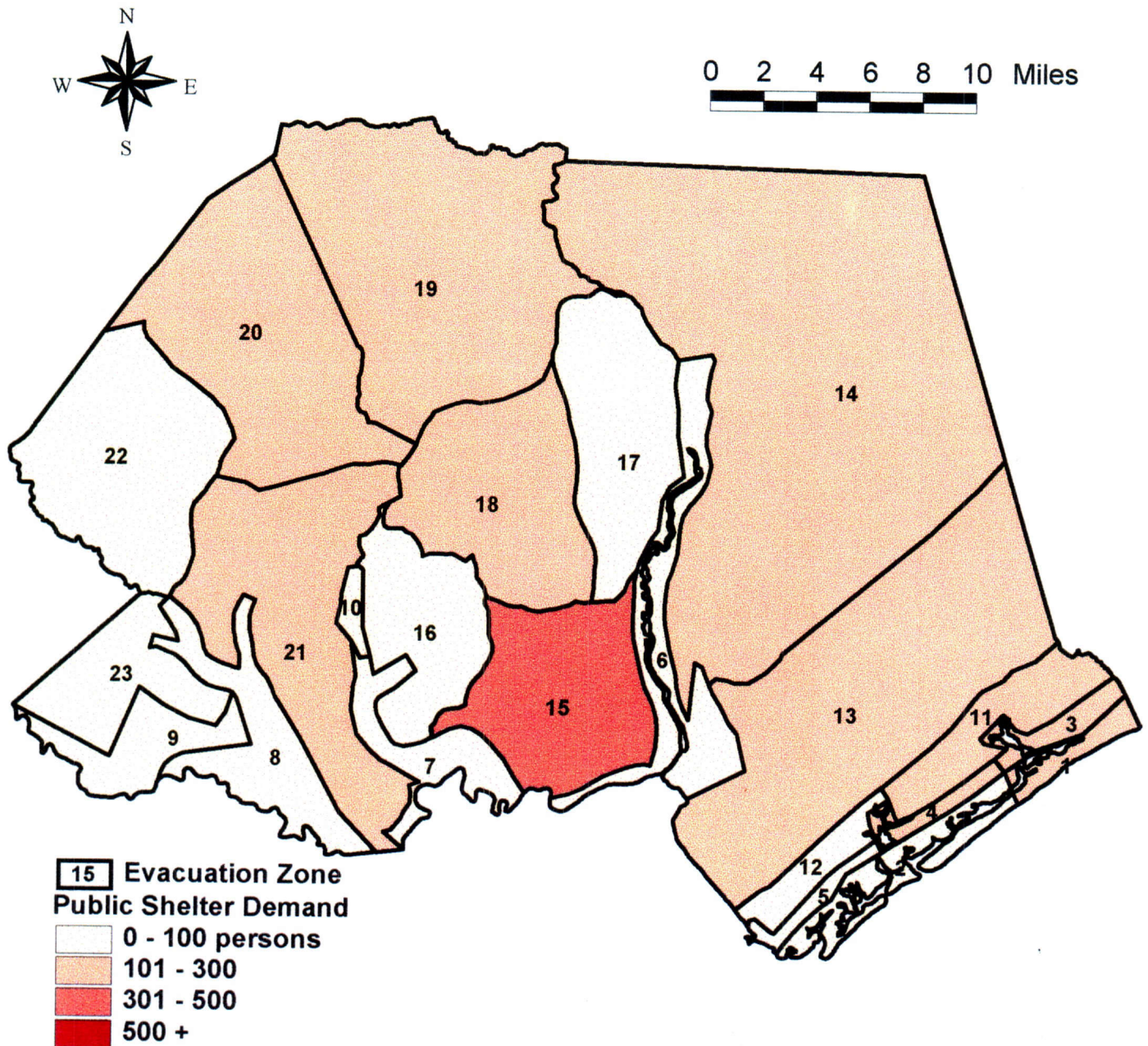
New Hanover County

North Carolina Hurricane Evacuation Restudy

Figure 3-14

Public Shelter Demand

Category 1-2 Hurricane
Low Tourist Occupancy



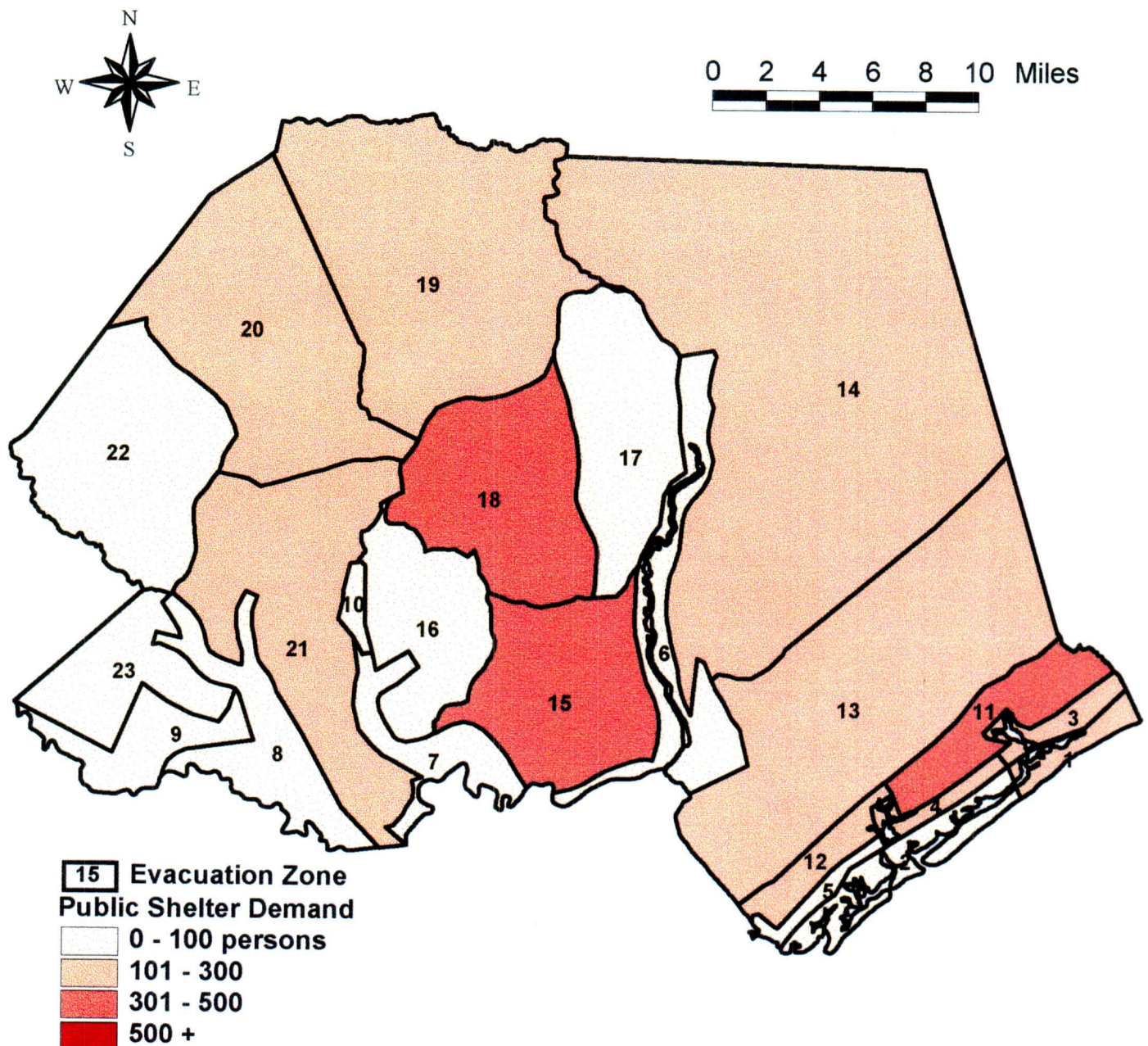
Pender County

North Carolina Hurricane Evacuation Restudy

Figure 3-15

Public Shelter Demand

Category 3-5 Hurricane
High Tourist Occupancy



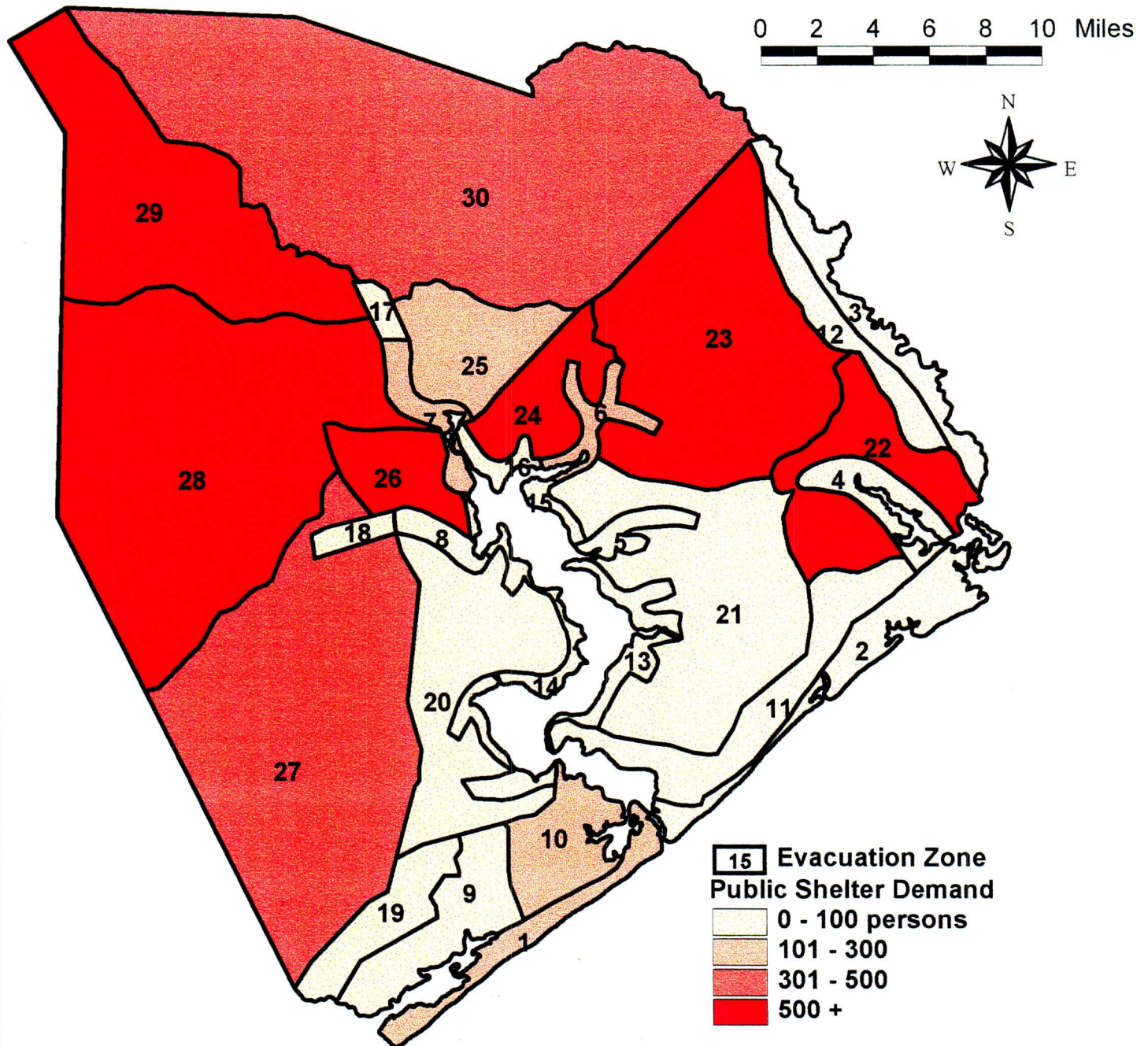
Pender County

North Carolina Hurricane Evacuation Restudy

Figure 3-16

Public Shelter Demand

Category 1-2 Hurricane
Low Tourist Occupancy



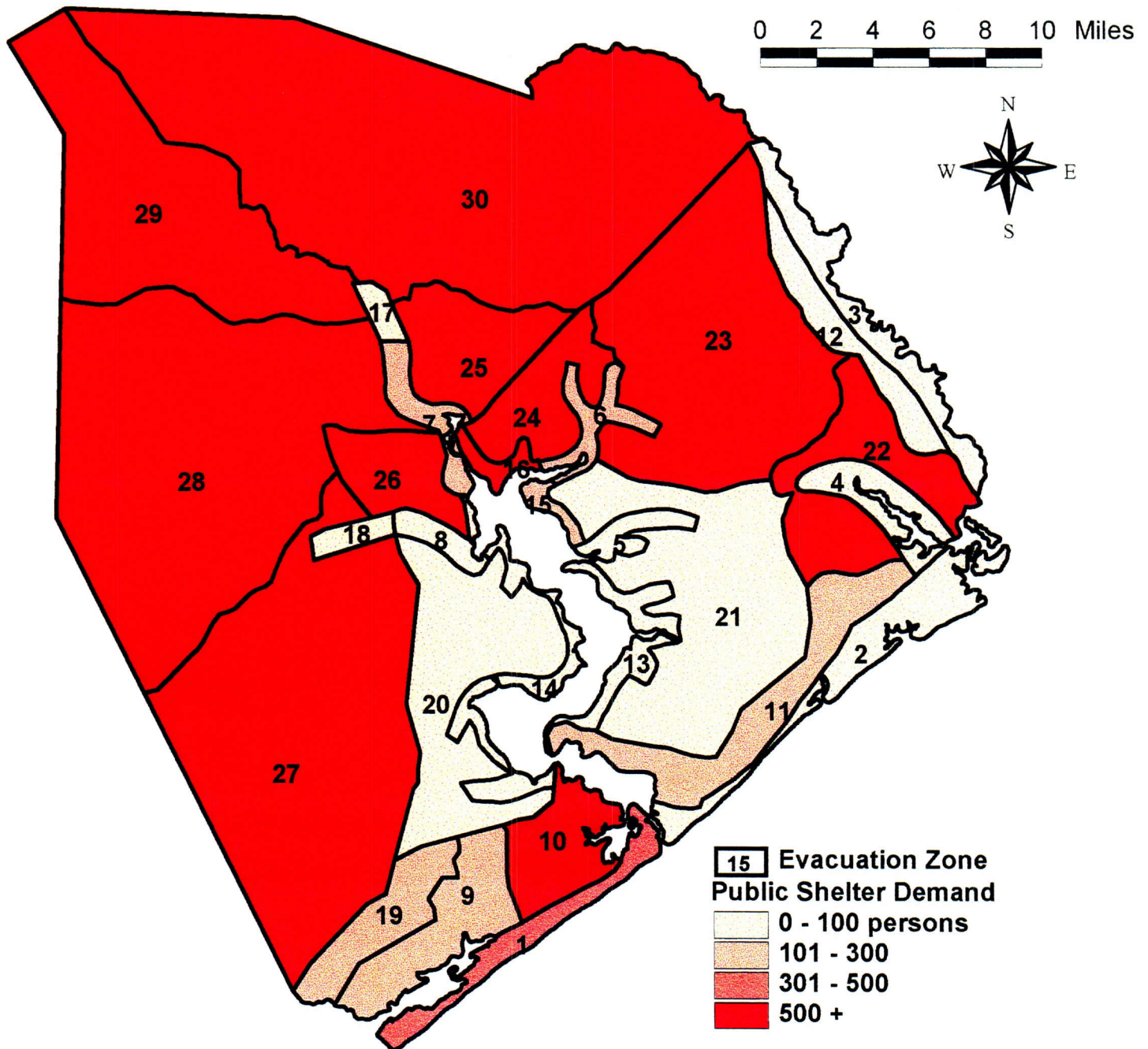
Onslow County

North Carolina Hurricane Evacuation Restudy

Figure 3-17

Public Shelter Demand

Category 3-5 Hurricane
High Tourist Occupancy



Onslow County

North Carolina Hurricane Evacuation Restudy

3.4 EVACUATION TRAFFIC VOLUMES AND CRITICAL ROADWAY SEGMENTS

The Transportation Model Support Document Appendix provides the assigned evacuating vehicle figures by roadway segment for each 1996 storm scenario by county. In addition, the Appendix provides an evacuating vehicles to service volume ratio calculated for each roadway segment by scenario. Those segments with the highest evacuation vehicles to service volume ratio were considered to be critical links for evacuation under a particular scenario. These congested areas control the flow of evacuation traffic during a hurricane evacuation and are key areas for traffic control and monitoring. (These ratios should not be confused with the v/c ratios used in traffic engineering to describe Level of Service).

Table 3-2 lists the roadway segments in each county that will control the flow of evacuation traffic. Figures 3-18 through 3-25 illustrate potential evacuation traffic congestion by roadway segment by storm scenario and county.

In terms of major hurricanes, in addition to those areas just listed, one must look at bottlenecks beyond the study area's border. Inland bottlenecks that may occur include:

- US 74/I-95 interchange on ramps
- US 258/US 70 intersection at Kinston
- US 17/NC 58 intersection at Maysville
- US 17/US 70 interchange at New Bern

Table 3-2

CRITICAL ROADWAY SEGMENTS
North Carolina Hurricane Evacuation Restudy

Brunswick County

NC 133 and NC 211 intersection northwest of Southport
NC 130 out of Holden Beach
NC 87 and US 17 intersection at Bell Swamp
NC 87 and US 74/76 intersection
US 17 intersections with NC 904, NC 130, and NC 211

New Hanover County

Carolina Beach Road south of and at Monkey Junction
College Road and Oleander Drive intersection
Cape Fear River Memorial drawbridge
Market Street and Eastwood Road intersection

Pender County

NC 210 from US 17 to I-40
Ocean Boulevard From Surf City to NC 50
US 17/NC 50 intersection at Holly Ridge in Onslow County
NC 210 on ramp to I-40 northbound

Onslow County

Marine Boulevard between Lejeune Boulevard and NC 53
US 17 and US 258 intersection west of New River
US 17/NC 50 intersection at Holly Ridge
NC 24 and US 17 intersection
NC 210 and NC 172 (Four Corners) intersection
US 17 and NC 210 intersection

Evacuation Traffic Congestion

Category 1-2 Hurricane
Low Tourist Occupancy



15 Evacuation Zone
Evacuation Traffic Congestion
 0 - 1 hours of travel demand
 1.01 - 3
 3.01 - 4
 4.01 - 6
 6.01 +

Brunswick County

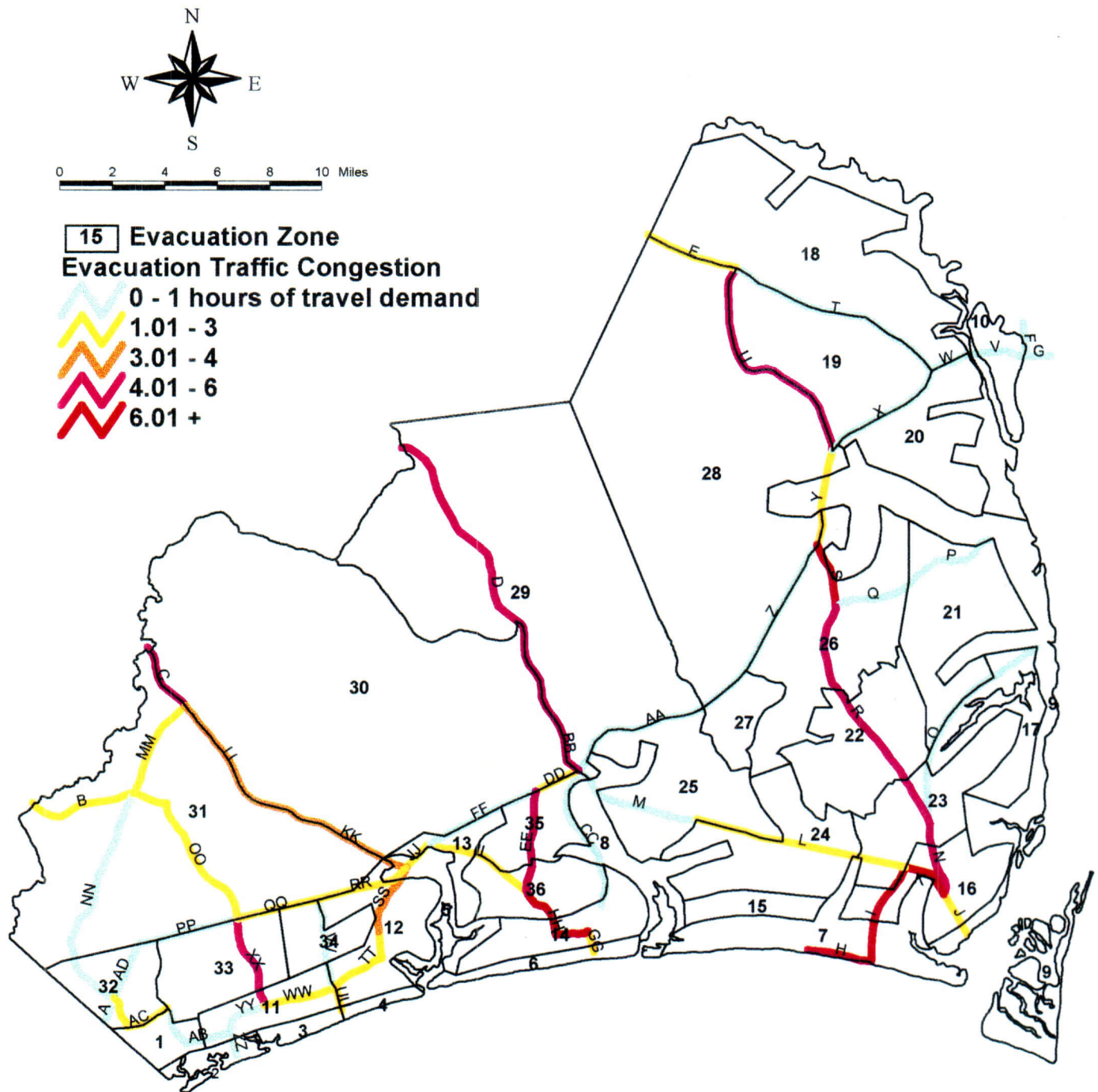
North Carolina Hurricane Evacuation Restudy

Figure 3-19

Evacuation Traffic Congestion

Category 3-5 Hurricane

High Tourist Occupancy



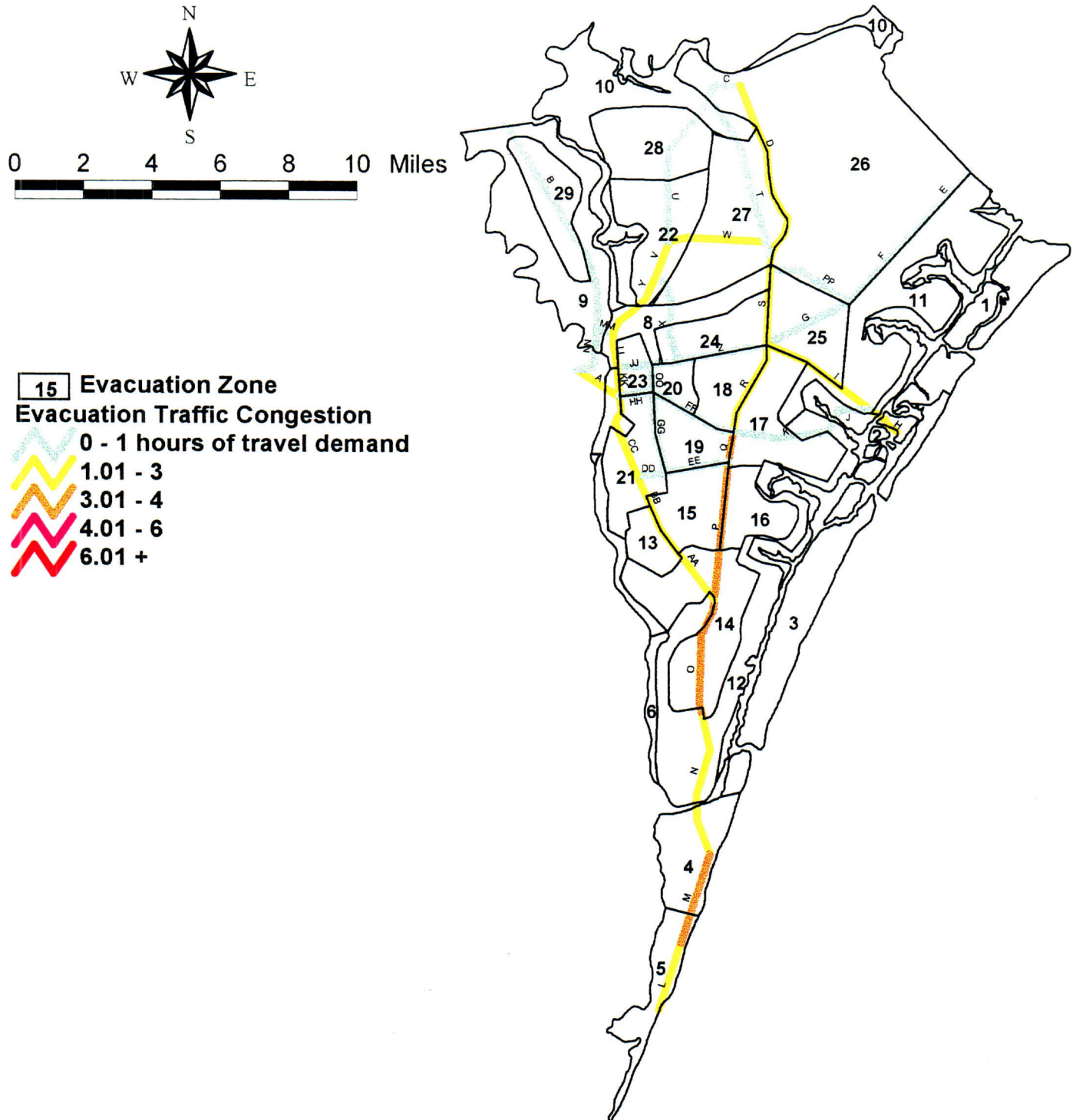
Brunswick County

North Carolina Hurricane Evacuation Restudy

Figure 3-20

Evacuation Traffic Congestion

Category 1-3 Hurricane
Low Tourist Occupancy



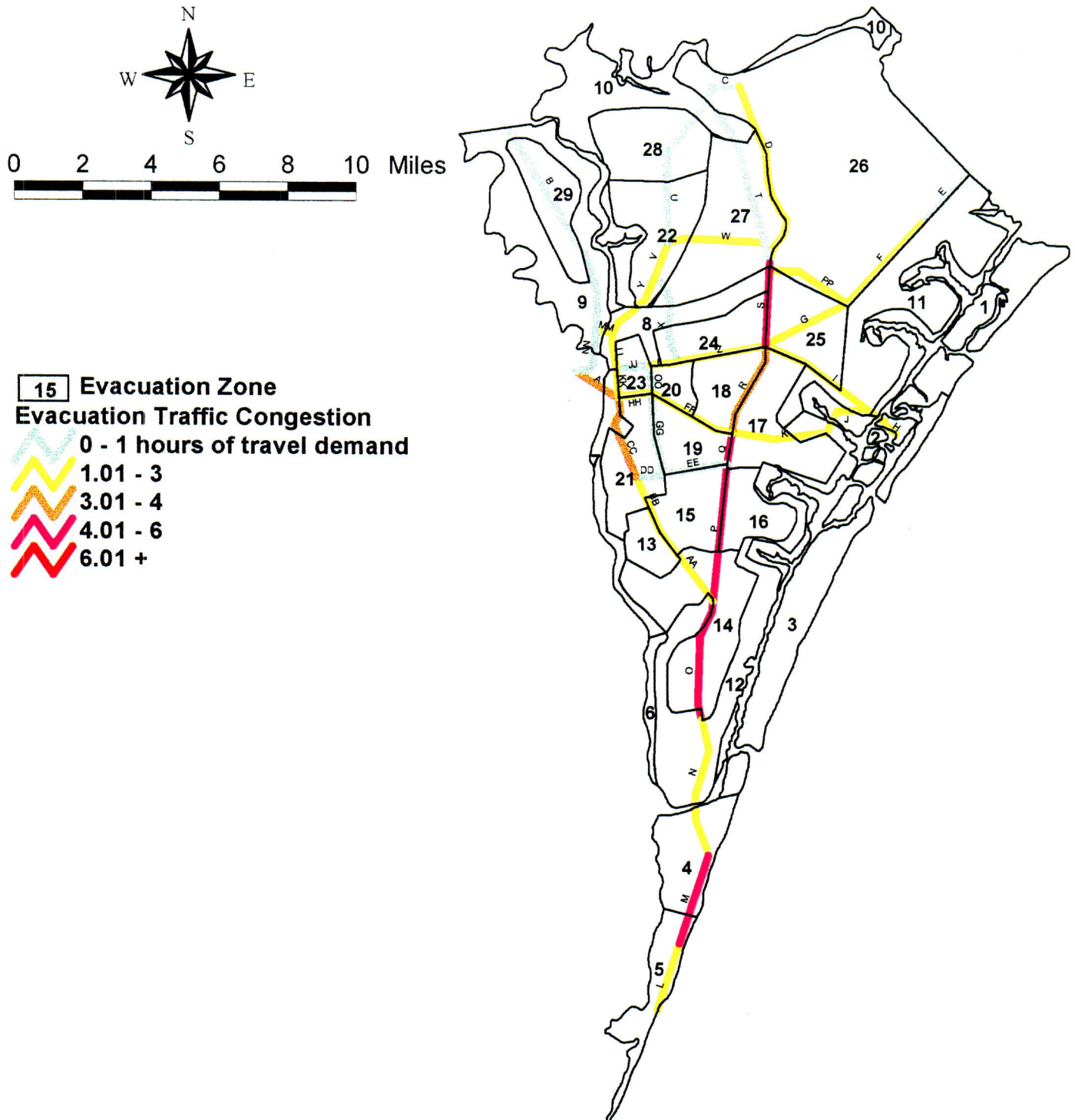
New Hanover County

North Carolina Hurricane Evacuation Restudy

Figure 3-21

Evacuation Traffic Congestion

Category 4-5 Hurricane
High Tourist Occupancy



New Hanover County

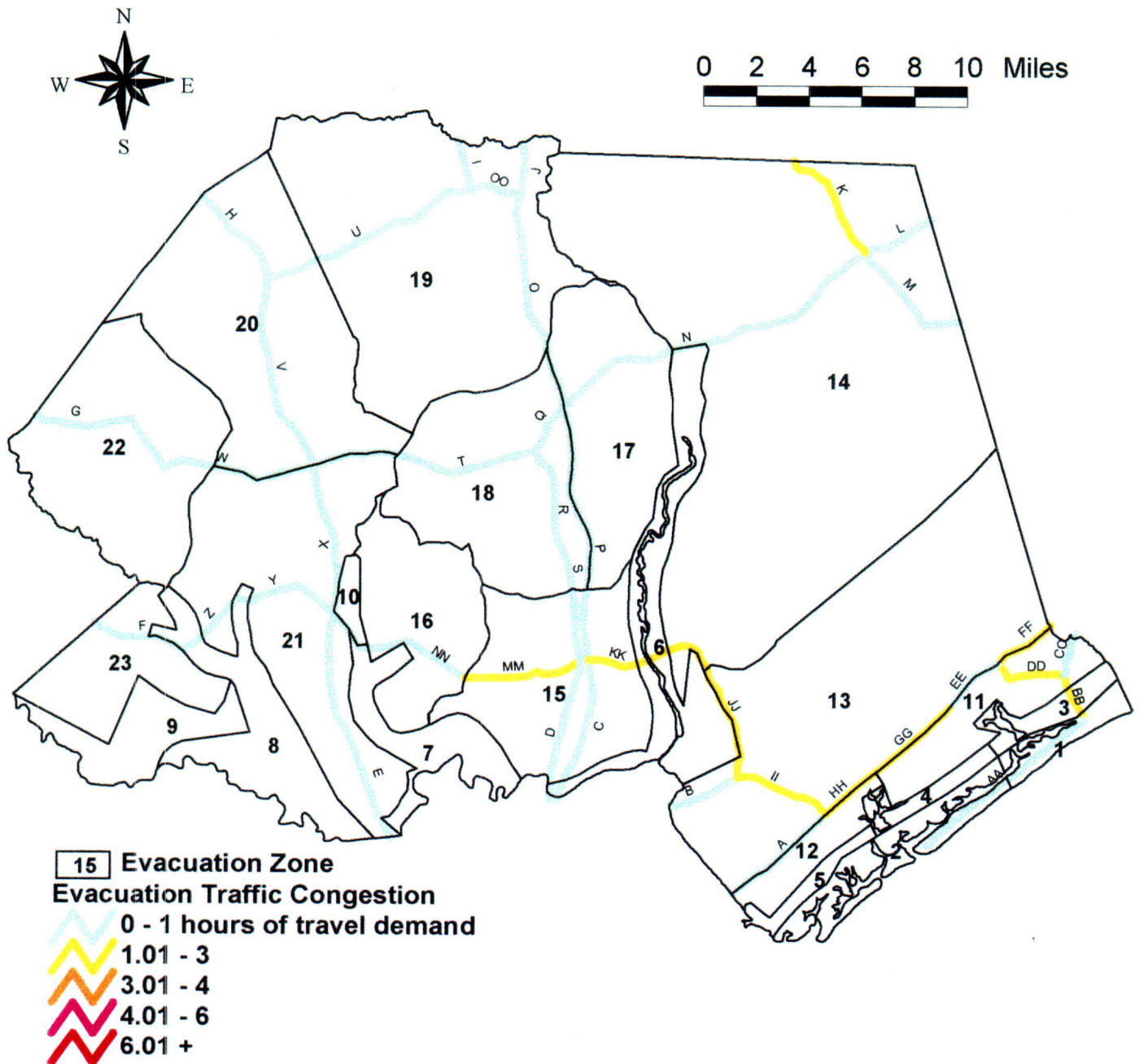
North Carolina Hurricane Evacuation Restudy

Figure 3-22

Evacuation Traffic Congestion

Category 1-2 Hurricane

Low Tourist Occupancy



Pender County

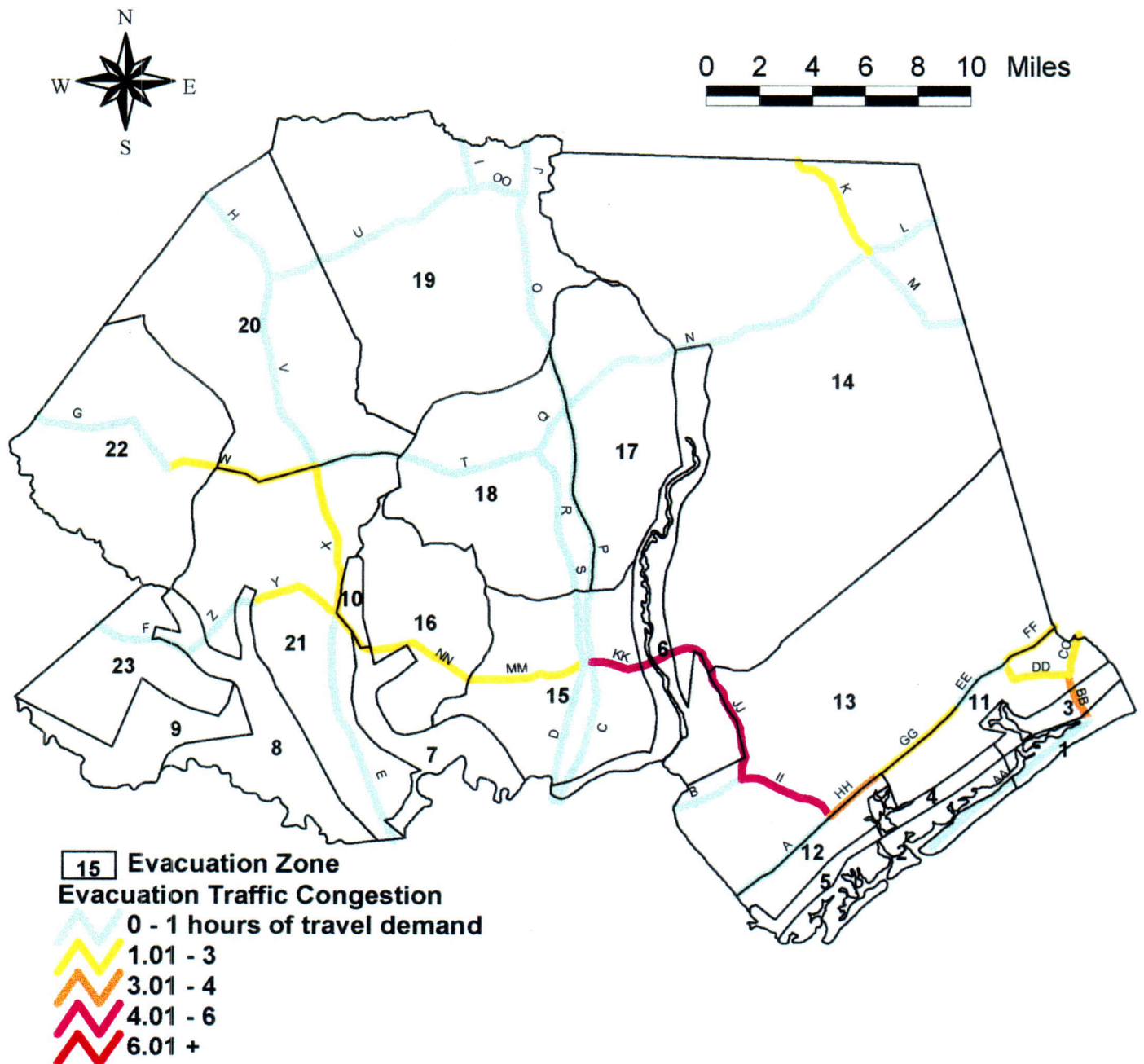
North Carolina Hurricane Evacuation Restudy

Figure 3-23

Evacuation Traffic Congestion

Category 3-5 Hurricane

High Tourist Occupancy



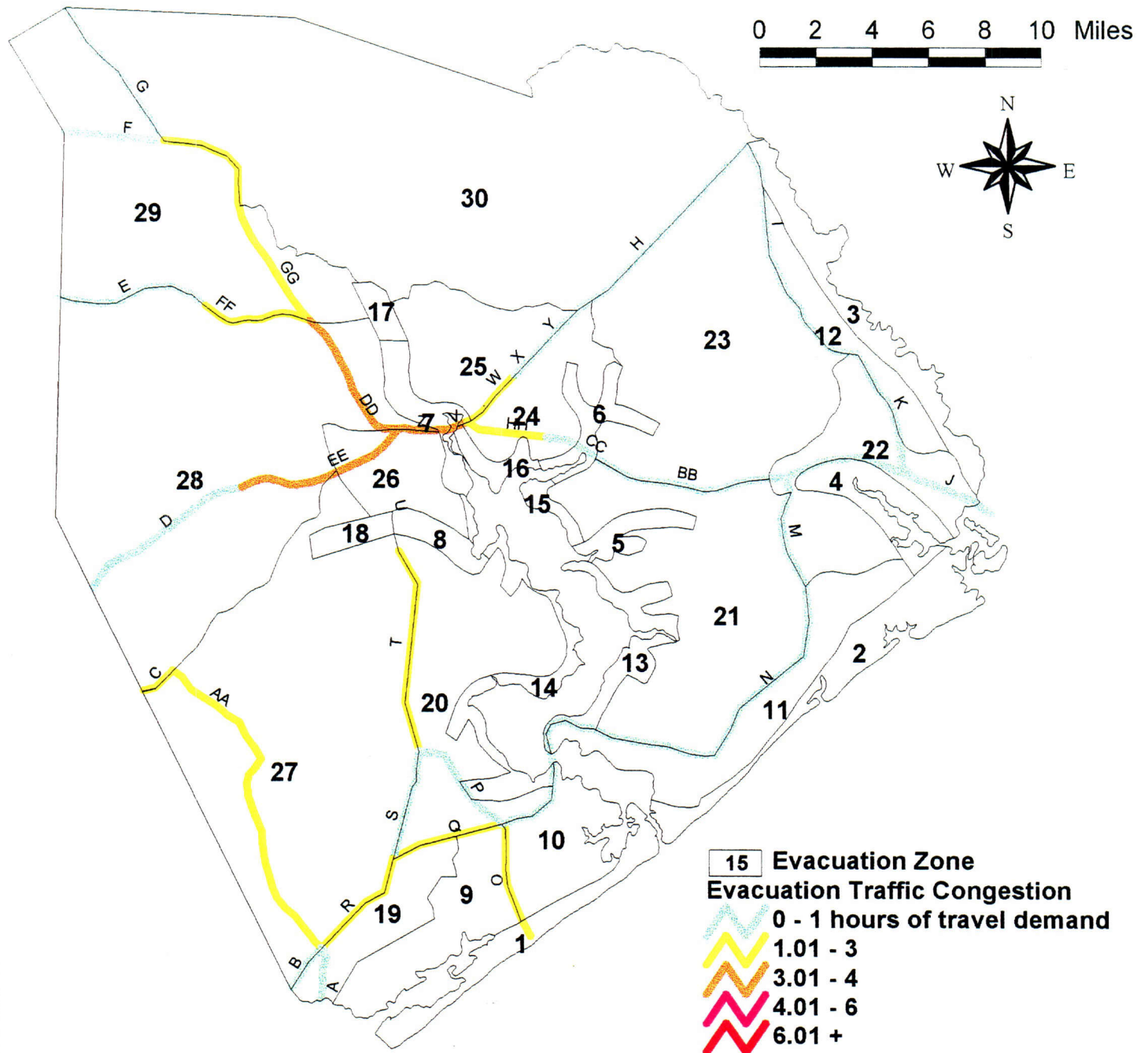
Pender County

North Carolina Hurricane Evacuation Restudy

Figure 3-24

Evacuating Traffic Congestion

Category 1-2 Hurricane
Low Tourist Occupancy



Onslow County

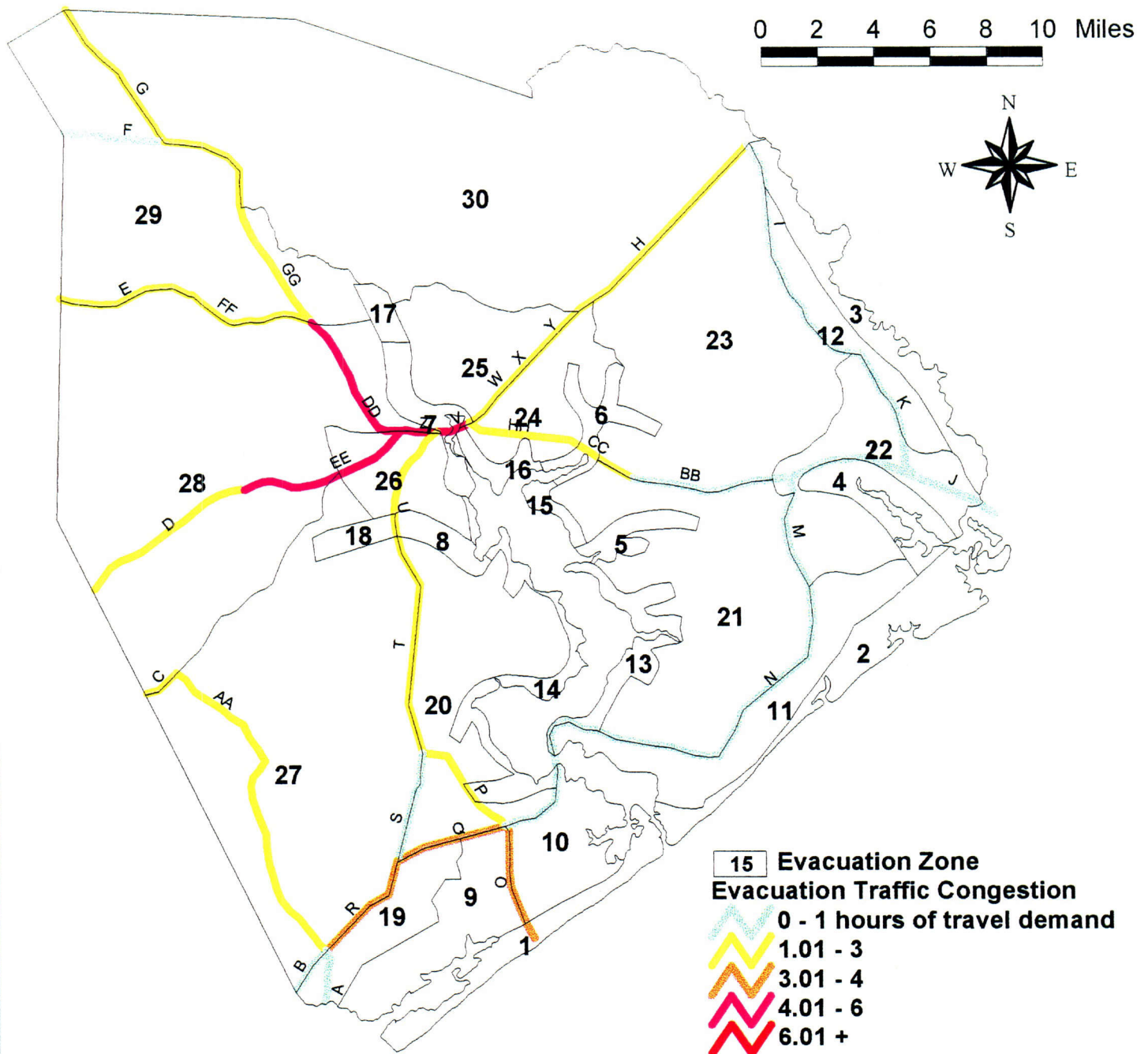
North Carolina Hurricane Evacuation Restudy

Figure 3-25

Evacuating Traffic Congestion

Category 3-5 Hurricane

High Tourist Occupancy



Onslow County

North Carolina Hurricane Evacuation Restudy

3.5 ESTIMATED EVACUATION CLEARANCE TIMES

An important product of the transportation analysis is the clearance times developed by storm scenario and by behavioral characteristic for each county. Clearance time is one of two major considerations involved in issuing an evacuation order or advisory. The other time aspect which must be weighed is the arrival of sustained tropical storm winds. Figure 3-26 illustrates these two timing issues of evacuation and their relation.

Clearance time is the time required to clear the roadway of all vehicles evacuating in response to a hurricane situation. Clearance time begins when the first evacuating vehicle enters the road network (as defined by a hurricane evacuation behavioral response curve) and ends when the last evacuating vehicle reaches an assumed point of safety. Clearance time includes the time required by evacuees to enter the road network (referred to as mobilization time), the time spent by evacuees traveling along the road network due to traffic congestion (referred to as queuing delay time). Clearance time does not relate to the time any one vehicle spends traveling on the road network and does not include time needed for local officials to assemble and make a decision to evacuate.

Tables 3-3 presents the hurricane evacuation clearance times developed for each county for the 1996 storm scenarios. Over 60 clearance time runs were developed based on differing intensity of hurricanes, evacuation area assumptions, rapidity of response evacuees, and differing tourist seasons. Clearance times in New Hanover County may vary slightly due to the presence of heavy or light background traffic. "Heavy background" traffic refers to evacuation situations where levels of network background traffic at the start of an evacuation are similar to peak period traffic levels on a typical work day. "Light background" traffic refers to evacuation situations where background traffic is light at the start of an evacuation such as during nighttime evacuation. Except for Brunswick County in a peak tourist situation, clearance times generally fit well within a 12 hour block of time which fits well with the National Hurricane Center's warning capabilities.

COMPONENTS OF EVACUATION TIME

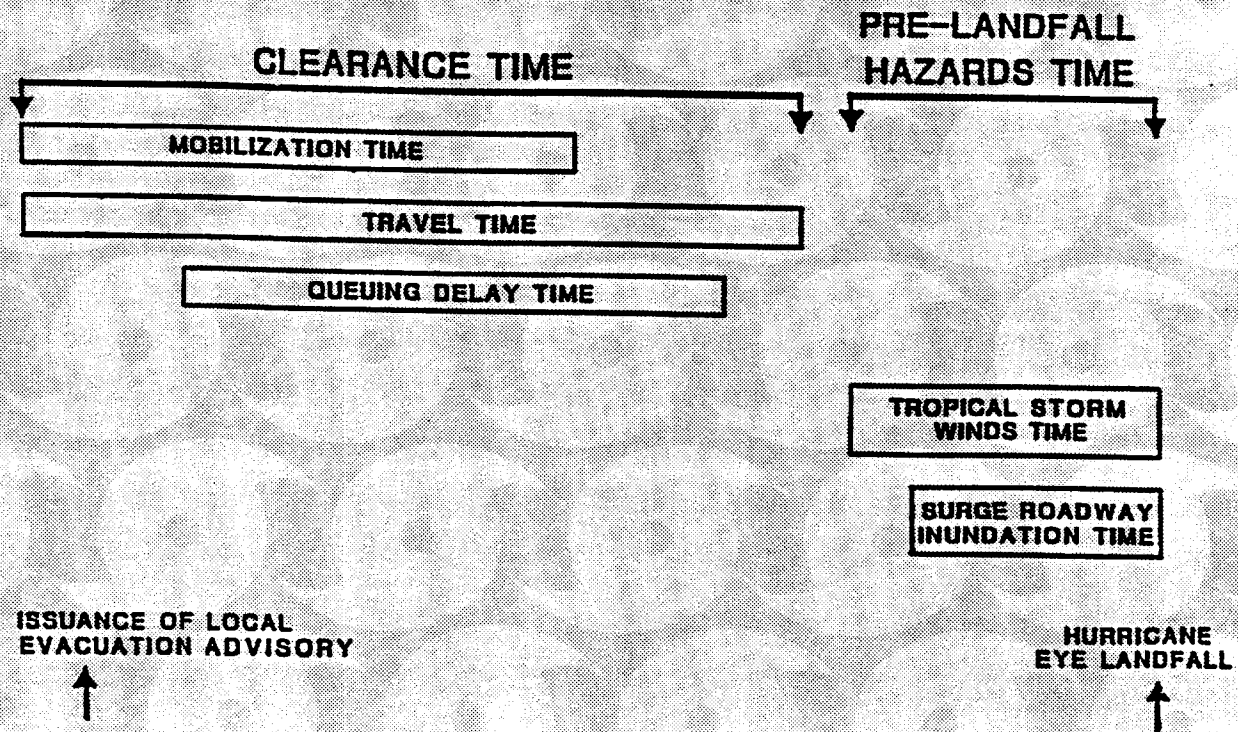


Figure 3-26

Table 3-3

CLEARANCE TIMES (IN HOURS)
North Carolina Hurricane Evacuation Restudy

Brunswick County

	Low Tourist	Medium Tourist	High Tourist
<u>Category 1-2 Hurricane</u>	<u>Occupancy</u>	<u>Occupancy</u>	<u>Occupancy</u>
Rapid Response	7 ¼ hours	9 ½	12 ¾
Medium Response	8	10 ¼	14 ½
Long Response	9 ½	11 ½	16 ½
 <u>Category 3-5 Hurricane</u>			
Rapid Response	7 ½	10 ¼	13 ½
Medium Response	8 ¼	11	15
Long Response	9 ½	12 ¼	17 ¼

New Hanover County

	Low Tourist	High Tourist
<u>Category 1-3 Hurricane</u>	<u>Occupancy</u>	<u>Occupancy</u>
Rapid Response	5 ½	7
Medium Response	6 ½	8 ¼
Long Response	9 ½	10 ¼
 <u>Category 4-5 Hurricane</u>		
Rapid Response	6 ½	7 ¾
Medium Response	7 ¼	9 ¼
Long Response	9 ½	11 ¼

Table 3-3(cont'd)

CLEARANCE TIMES (IN HOURS)
North Carolina Hurricane Evacuation Restudy

Pender County

	Low Tourist	High Tourist
<u>Category 1-2 Hurricane</u>	<u>Occupancy</u>	<u>Occupancy</u>
Rapid Response	4 ¼	4 ¾
Medium Response	6 ¼	6 ¼
Long Response	9 ¼	9 ¼

Category 3-5 Hurricane

Rapid Response	5	6
Medium Response	6 ¼	6 ½
Long Response	9 ¼	9 ¼

Onslow County*

	Low Tourist	High Tourist
<u>Category 1-2 Hurricane</u>	<u>Occupancy</u>	<u>Occupancy</u>
Rapid Response	5	5 ½
Medium Response	6 ¼	6 ½
Long Response	9 ¼	9 ¼

Category 4-5 Hurricane

Rapid Response	6 ½	7 ½
Medium Response	7 ¼	8 ¼
Long Response	9 ¼	9 ½

* Note: If a storm scenario compels Camp Lejeune to move equipment and personnel out of Onslow County and the base has not completed its movement before the general population evacuates, approximately three hours of clearance time should be added to the above applicable figure.

3.6 TRAFFIC CONTROL MEASURES

Some general recommendations concerning traffic control are as follows:

- ~ Brunswick County evacuees desiring to go northbound should be encouraged to travel west to I-95 or to use US 421. If Brunswick evacuees attempt to access I-40 in Wilmington, they could negatively impact New Hanover County evacuation operations depending on the storm scenario.
- ~ Where counties have sufficient personnel resources, officers should be stationed at critical intersections to facilitate traffic flow. Where intersections will continue to have signalized control, signal patterns providing the most "green time" for the predominant evacuation travel direction should be activated.
- ~ If possible, arrangements should be made with tow truck operators so that they are pre-positioned along key travel corridors and critical roadway facilities such as bridges.
- ~ All draw/swing bridges needed for evacuation should be locked in the "down" position during a hurricane warning if possible. Boat owners must be made aware of flotilla plans and time requirements for securing vessels.
- ~ The state and counties should jointly work on a statewide evacuation and shelter monitoring system which would monitor travel flow at key locations and report traffic tie ups/shelter availability to the general public as they evacuate.

4.0 POTENTIAL GIS HURRICANE PREPAREDNESS ACTIVITIES

Although the project resources dedicated for GIS application were allocated to mapping and graphics, PBS&J provides some general thoughts in this final section concerning the use of GIS for hurricane preparedness activities. Much of this information was developed and learned through PBS&J's work for the Dade County, Florida MPO on the Dade County Transportation's System Hurricane Emergency Preparedness Study and recent work for the Palm Beach County, Florida MPO on the Supplemental Emergency Transportation Planning Analysis.

GIS is a powerful tool for predicting, analyzing and displaying data related to a community and its vulnerability to hurricanes. Because hurricanes are not just a dot on a map, but are systems which cover many square miles, they can be superimposed on a county's geography and related databases to anticipate damage and to plan for contingencies. If a county knows the design characteristics of different features of a facility or system and all the elements of a system have been captured in a GIS database, storms of various strengths, size, and direction can be overlaid to predict the number of system elements that will be destroyed.

GIS can also be used in a study to help tabulate the number of people and vehicles in various zones and flood areas. As future databases are developed concerning population and land use, GIS can tabulate the vulnerability statistics of each county for that year. GIS can be used in a pre-storm manner to keep track of evacuation zone and road network features. Many relevant databases for North Carolina coastal areas may be available through other local agencies or state agencies and used in this analysis mode.

Mapping developed in this study can be plotted at large scale sizes to assist in recovery after a storm strike. Overlays concerning long term shelter status, debris cleanup progress, and staging areas can be mapped and distributed to clean up staff and local officials.

Emergency management staff should serve on each county's GIS development committee (where applicable) and share data files and technology. These efforts should continue so that data can be captured for hurricane emergency planning. PBS&J, as a part of this project, is turning over GIS developed files for each county's continued use.

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